# DEFENCE OF THE SEA-COAST OF THE UNITED STATES

ABBOT.

# COURSE OF LECTURES

UPON THE

# DEFENCE

OF THE

# SEA-COAST OF THE UNITED STATES

DELIVERED BEFORE THE

U. S. NAVAL WAR COLLEGE

BY

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# CONTENTS.

## FIRST LECTURE.

### GENERAL CONSIDERATIONS.



## SECOND LECTURE.

### ECONOMY IN COAST DEFENCE.



## THIRD LECTURE.

### SELECTING THE SITE; HORIZONTAL FIRE.



## FOURTH LECTURE.

### MORTARS AND SUBMARINE MINES.



## FIFTH LECTURE.

### SEA-COAST FORTRESSES.

# FIRST LECTURE.

## GENERAL CONSIDERATIONS.

Introduction—The art of war as applied to Coast Defence ; strategy ; grand tactics ; logistics ; art of the Engineer—Probable nature of the attack ; needful calibres ; number of guns ; guns ashore and guns afloat ; naval tactics against forts.

In accepting the invitation to lecture before the Naval War College on our Coast Defences, I duly appreciated not only the courtesy extended by it to the body of Military Engineers which I represent, but also the assistance to be received from an interchange of views upon debatable points where the duties of the land and naval forces follow parallel lines and demand mutual co-operation of the most cordial character. Good cannot fail to result from dropping occasionally the technical study of our respective specialties, and taking a general view of what is needed by the country to prevent its thousands of miles of coast line from opening to an enemy modes of attack where heavy blows may be delivered with little risk, and where decisive results may be attained without affording us a chance of bringing our power as a nation to bear.

The great mass of our population is now, and from the nature of things must remain, ignorant of the requirements of National Defence. The duty of considering what should be done, and how it should be done, has been devolved upon a little band of professional Army and Navy men, largely graduates of West Point and Annapolis, small in numbers and

with no ready mode of interchanging views. Yet we are expected to elaborate a wise and comprehensive system of coast defence; and when the evil day comes we shall justly and mercilessly be held responsible if, blinded by professional technicalities, we have failed to grasp the problem in its entirety. We are too much tempted to forget that our responsibility is by no means limited to details. We are expected to form broad and harmonious views of what the Nation needs; and only in this way shall we secure for our opinions that weight which unanimity among experts always carries with intelligent men who feel themselves to lack technical information. What the Army and Navy agree in recommending will not be lightly thrust aside; and I know of no better mode of inducing unanimity of opinion than the plan of mutual co-operation in study introduced by the founders of the Naval War College.

In preparing these lectures I have borne in mind the professional character of the audience, which would render details on such subjects as modern guns, modern armor, modern torpedoes, and submarine mines as wearisome as a twice-told tale; they will only be touched upon when necessary to make my meaning clear. On the other hand, it would tax your patience to spend time in elaborating details of land construction, such as foundations, strength of materials, and other technicalities of the profession which, of vital importance to the constructor, can have no interest to a naval officer. In a word, I shall try to present the general subject of Coast Defence from the point of view of an Army Engineer, omitting technicalities with which you are familiar and also those in which you have no interest. In return I shall be grateful for suggestions as to any matters which may appear doubtful as seen from a naval point of view.

## THE ART OF WAR AS APPLIED TO COAST DEFENCE.

General Brialmont justly observes in his latest treatise on Fortification that the defence of a sea-coast resembles that of a chain of rugged mountains. At most points it is unassailable. The few deep bays and mouths of rivers, which have attracted commerce and caused the erection of cities and the establishment of dock-yards and naval stations, are like the natural passes through the mountains that have created the roads and villages by which the enemy must move to the attack.

There is, however, a marked difference in the nature of this attack. The army advances like a swarm of ants, imposing in numbers but weak in individual power; the fleets approach like a platoon of elephants in the days of Alexander, terrible as individuals, but few in number and handicapped by difficulties in the use of their weapons.

It is only two centuries since admirals stepped from the quarter-deck to command armies in the field, and since generals won victories upon the water by applying land tactics. The Services have long been distinct, but it does not follow that we may not still derive mutual benefit by approaching this problem of coast defence from our different standpoints, and applying principles learned in different fields of duty.

This is the more true because works of coast defence are less a matter of pure fortification than an application of technical details which are becoming more complex from year to year. The Engineer charged with planning them is compelled to study the subject somewhat from a naval standpoint, because the arrangements of all defensive works are regulated by the mode of attack; and the latter, which has undergone radical changes in the last few

years, is, in the absence of actual experience in war, still far from being definitely established. Nevertheless, in its general features, Coast Defence is a problem to which many rules derived from land operations are applicable.

The Art of War is usually subdivided by military writers into five principal branches: Strategy, Grand Tactics, Logistics, Elementary Tactics, and the Art of the Engineer. Rules of each of these branches, except perhaps of Elementary Tactics, find an application more or less important in the problem of Sea-Coast Defence.

**Strategy.**—The art of making war upon the map is especially concerned with the selection of the points for permanent occupation, and with the operations of the fleets which in coast defence represent the movable forces of the Nation. No principles are better established than (1) that the mass of our forces should be thrown upon fractions of the enemy ; (2) that, so far as practicable, we should operate upon his communications without endangering our own ; (3) that the effort should be energetic and in concert throughout the theatre of war ; and (4) that even in a defensive campaign vigorous offensive operations should never be neglected when practicable.

Every principle of strategy is therefore violated in adopting for sea-coast defence a plan which contemplates the leaving of our important strategic positions without permanent fortifications, and looking to defending them by fractions of our Navy shut up in them at the outbreak of war. Such a project would find its parallel in an army subdivided, interned in strong places, and left to be overmastered successively by the united strength of the enemy. All experience in land campaigns warns us that by such a system defeat would be assured before the first gun was fired.

From this point of view it is evident that in selecting the positions on our sea-coast to be permanently defended, we must have regard not only to security for our navy-yards and depots, for our great fleet of coastwise trading vessels, for our important cities—in a word, for the points which a hostile fleet bent on scourging us into accepting peace by inflicting pecuniary damages would select for attack—but also to providing safe rendezvous for our fleets whence they can sally at will to assume the offensive.

The necessity of leaving our fleets free to carry, so to speak, the war into the enemy's country whenever occasion offers, is no new theory resulting from the peculiar conditions of sea-coast defence to-day. The idea was urged in the Senate by Mr. Webster, with his usual eloquence, in 1838; and was so well expressed by Admiral Dupont in 1851 that I cannot do better than quote his exact language. He wrote:

"I beg leave to express an emphatic dissent from all theories having for their object the substitution of active ships of war for permanent works. This would be placing the Navy in a false position before the country; giving it duties to perform for which its organization is inapplicable; preparing for its future discredit and loss, through failures to execute that which should never have been undertaken, which is not embraced in the general scope and design of a naval establishment.

"To retain the Navy for harbor defence was entertained at the commencement of the last war with England; the proposition to do so sprung from the apprehension that it could not compete with the vastly superior English force upon the ocean. But at that time some brave and sagacious officers in the high ranks saved the Navy from the fate that threatened it, and to these gentlemen it owes all its sub-

sequent honors, usefulness, and prosperity. If any such ideas prevail at this day, in or out of the profession, those holding them would do well to pause and consider what the Navy would have lost, and what the country would have lost, if our ships of war had at that eventful period been deprived of the opportunity of filling so bright a page in the Nation's history by their achievements upon the ocean."

These opinions as to the true strategic functions of the Navy are now, it is believed, generally accepted, and plans for coast defence should be so arranged as to give them full effect wherever possible; *i.e.*, any complete system must be planned to furnish safe bases along the coast from which offensive operations can be undertaken and in which security may be found in the event of disaster.

This matter was carefully considered by the Endicott Board of 1886, and provision was made for such rendezvous at Portland, at Boston, at Narragansett Bay, at New York, at the Delaware, at Hampton Roads, at the mouth of the Mississippi, and at San Francisco; *i.e.*, at eight of the eleven ports at which fortifications were reported as "most urgently required." Great Britain has already prepared two such rendezvous in our waters for her own use—one at Halifax and one at Bermuda; and rumor reports that she has another in view in the near future at Victoria.

Strategic considerations of a special character are suggested in connection with Portland Harbor; they give it a prominence to which the wealth and importance of the city itself could advance no claim. It is the terminus of the Grand Trunk Railroad and the natural winter outlet of the Dominion of Canada. Its importance is perfectly appreciated by Great Britain. Colonel Strang, R.A., in a lecture before the Royal United Service Institution in 1879 used the

following language: "Without the Canadian Pacific Canada is a cul-de-sac. The struggling nationality resembles a young giant whose careless parents allowed one nostril to be stuffed up by the loss of the unfrozen seaports of the State of Maine; and now, after giving up Oregon and the San Juan passage, that other Canadian nostril, we are threatened with the secession of British Columbia, which can neither be defended nor traded with. . . . Fortunately at Halifax we have retained some of the *ultimæ rationes regum et populorum.* We need not, therefore, discuss the defence of this fortress and harbor, which, however valuable in other senses, can in no sense be considered a safe base for operating in the inland defence of Canada; for the treaty of 1842, which handed over the State of Maine, sends a wedge of territory up to within a few miles of the inter-colonial railroad which a handful of troopers could at any moment render unserviceable in a night, thus cutting off retreat to Halifax or succor from thence to the upper provinces. It is true that detachments were sent from Halifax during the *Trent* difficulty; but the United States were at that time disunited States."

The value of Portland as a temporary British naval station during a war with the United States would be sure to attract attention; and if, in case of heavy American reverses, our opponent should be in a position to demand a land indemnity as one of the conditions of peace, as did Germany in the late war with France—to whom the idea doubtless seemed as preposterous at the outset as it does to us to-day—probably no section of the country would be so likely to be desired as this magnificent port. For this reason it behooves us to hold it strongly against any possible attack. If Metz and Strasbourg had been unoccupied by a German army when the terms of

peace were agreed upon, they might have escaped their fate.

The strategic importance of Boston in a naval war is self-evident. A small force here would cover the entire coast from Cape Cod to New Brunswick against marauding expeditions detached from a fleet operating against New York. It forms the natural base for fitting out offensive operations against Halifax and the St. Lawrence. Lastly, when properly defended, it would afford refuge to the whole fleet of New England fishing and coasting vessels.

Narragansett Bay covers the entrance to Long Island Sound and all the small harbors on its shores. An enemy passing Montauk Point would leave his communications at the mercy of a much smaller fleet lying here behind land defences affording security against direct attack. Gardiner's Bay, at the eastern end of Long Island, would be perhaps a better position; but it is not so easily defended by forts, and it lacks the importance of Narragansett Bay in other respects. Admiral Simpson, in whose professional judgment I have great confidence, has always urged the importance of a large naval establishment at New London, not only from its natural advantages, but also from its strategic relations to Long Island Sound. Should such an establishment ever be created there, the local question of its land defences would be simple.

The supreme importance of New York, the commercial metropolis of our Atlantic seaboard, is unquestioned. No demonstration is needed either as to the necessity of local defence or as to the facilities the port offers for offensive sallies in every direction.

Hampton Roads bear to Chesapeake Bay a relation similar to that of Narragansett Bay to Long Island Sound. A small force driven from the ocean by a superior fleet could take refuge behind a forti-

fied line based on Fortress Monroe, and from this secure position could threaten the passage between the Capes so effectually that no enemy could afford to operate against Baltimore or Washington without leaving behind at least an equal detachment to cover his only route of communication with the ocean.

The fleet charged with the general defence of the Gulf Coast would find its principal base on the Mississippi; where, stationed centrally, it could operate at any point between the Capes of Florida and the Rio Grande so soon as the telegraph made the approach of the marauders known. It goes without saying that, in case of a war with Spain, Key West would become a place of great strategic importance by reason of its vicinity to Cuba, and the facilities it offers as a base for land operations against that island and for blockading its coasts. Controlling as it does the narrow channel leading from the South Atlantic Coast to the Gulf of Mexico, it must be firmly held in any maritime war, and especially in one with France or Great Britain, which have possessions in the West Indies.

The relations of San Francisco to the Pacific Coast are similar to those of New Orleans to the Gulf of Mexico; and in addition it would be our base for any offensive operations on the Pacific, at least until a new fortified position at Puget Sound is demanded by the growth of population in that direction.

These views as to the strategic points along our seaboard are based upon three beliefs: (1) that it will be long before we shall have a Navy strong enough to carry the war across the Atlantic and thus keep the enemy at home; (2) that present indications of awakened interest warrant the opinion that we shall soon have a Navy which, if afforded secure points of refuge, would by frequent sallies make its

influence felt against an attacking fleet too strong to be faced in a pitched battle, thus extending indirect protection to the small ports along our entire seacoast; and (3) that if we neglect to prepare these places of refuge, our new Navy may be swept from the ocean, as was the *Huascar*, or may be ignominiously captured in our harbors, as happened to the Danube squadron in the late Russo-Turkish war, and as has happened to fleets again and again in days gone by.

If we should fritter away our resources in constructing armored ships with a view to chaining them in harbors where local conditions make a land defence more economical—and this statement is true for all our ports except San Francisco and the mouth of the Mississippi—we should not only waste money but should also create a Navy ill-suited to perform the duties which sound strategic principles demand of that arm of the service. In my judgment, the Navy, like cavalry, loses half its power if not threatening the offensive.

I make no reference to the strategic use of torpedo-boat flotillas, because I am not sufficiently informed as to their ability to keep the sea in tempestuous weather, concerning which there appears to be some difference of opinion since the recent French evolutions. Of one thing, however, I am sure. These boats will play a very important part in connection with our projected land defences, as will be more fully elaborated hereafter.

**Grand Tactics.**—Grand tactics treat of the art of well combining and well conducting battles. In the shock of armies manœuvring for position much is necessarily left to chance, because neither combatant is possessed of the plans and views of his opponent, and accident or lack of time may compel the neglect of well-recognized rules. A seaport to be

fortified should be carefully studied in advance, and with ample time and means no such mistakes are justifiable.

On land the weak positions of a line of battle are usually the flanks; and if the line be too strong and well occupied for a front attack, the assailant usually manœuvres to turn one of them. But when the enemy is confined to his ships he can move only by navigable channels; we may with certainty foresee what, if any, flank operations will be practicable, and by preparing to meet them may compel him to either attack where we have carefully prepared a battle-field to give us every advantage, or, as has often happened, to abandon his intention of attacking. *This latter should be the aim of the Engineer in fortifying a harbor*, for it is an accepted principle never to seek a battle unless the chances of advantage which will accrue in case of success shall preponderate over the chances of loss if defeated; and this condition can rarely if ever be fulfilled in a battle fought to prevent the occupation of an important harbor by a hostile fleet.

The maxims of grand tactics applicable to coast defence teach us the following: (1) to provide for offensive movements of our own torpedo-boats, and of our armored ships if any be present. This principle forbids the closure of channels by obstructions which cannot be passed by our own vessels; (2) to so place our land guns as to assure their mutual support and their most effective service against the enemy. Mutual support is important to prevent the overwhelming of one battery by the concentration of superior fire, which is always to be expected in a deliberate attack. In discussing the defences of Spezzia the Italian engineers laid great stress upon this point; and a position which would permit an enemy to bombard the docks and navy-yard at a

range of only 4.6 miles was advocated, and I think has been adopted, rather than secure a longer range at the expense of exposing isolated turrets to a concentric fire; (3) to guard well the flanks by closing all unnecessary channels, and thus compel the enemy to make a direct attack or to make none at all—the application of this principle has been already considered; (4) to provide means for offensive returns against countermining operations in the absence of torpedo-boats of our own. This is the true function of movable torpedoes operated and directed from the shore. A purely passive defence, whether on land or sea, is rarely successful.

**Logistics.**—This branch of the art of war is concerned with the preparation in advance, with the proper storage, and with the transportation of all material needful for use in connection with the operations of an army. In sea-coast fortification it has to do with supplies of all kinds, and with preparations to receive and store them. Thus magazines and shell-rooms ample to contain the immense quantities of ammunition demanded by modern guns, and yet absolutely bomb-proof, are a necessity. Bomb-proof cover for the garrison, the stores, and the military material; safe covered passages for the movement of ammunition in action; protected routes for introducing the electric cables of the submarine mines; and many other matters too numerous to mention, pertaining to the domain of logistics, press upon the attention of the military engineer. The Navy has troubles of its own of a like character; but I think neither branch of the service has much to learn from a study of rules in logistics evolved from the experience of armies in the field.

**The Art of the Engineer.**—This branch of the art of war, which as applied to coast defence includes locating, planning, and constructing the fortifica-

tions, largely forms the subject of these lectures. It calls for an appreciation of the power and of the weakness of modern ships of war, of modern ordnance and torpedoes, and, in general, of the most effective and economical methods of securing every possible advantage to the defence by applying such means as are available. Each element must be considered and weighed as to its relative cost and relative efficiency. The funds allotted to sea-coast defences by all nations are limited, and what is wasted in injudicious expenditure will certainly be subtracted from some needful outlay. For example, nothing could be easier than to make an impregnable fort if cost were left out of consideration. Armor-plates, whether steel, or compound, or wrought iron, or chilled cast iron, can be made thick enough to keep out the projectiles of any gun now existing or which ever can exist. If three feet of armor will not do it, ten feet will. There is no limit to the security attainable in a land battery, where any weight whatever can be supported. But the skill of the engineer lies in a judicious estimate of what is needful and of what is superfluous, and in making his plans and applying his funds accordingly.

This principle has always governed the Engineer Department. By skilfully applying it to a problem all the elements of which were then known and admitted of computation, General Totten was able to give to the country what at their date were perhaps the most perfect sea-coast fortifications the world has ever seen, and to accomplish the task with funds which Congress was willing to grant.

But this is the age of progress. The introduction of the screw-propeller led to the use of guns throwing shells which no ships could endure, and hence to the introduction of armor. Then followed the long struggle for supremacy between ordnance and armor,

which unsettled all ideas and made the problem one rather of prophecy than of knowledge. This was the condition at the close of the civil war. It was the judgment of the best officers of the Corps of Engineers, shared and carried into effect by General Humphreys, that the time was ill-suited for the selection of a permanent system; but that all funds available could be wisely applied to inaugurating a system of earth-works which would meet the needs of the moment and would remain useful when a more definite estimate of what could be accomplished in armored ships and ordnance was possible.

This time has now come—at least as to the essential elements—and it is my purpose in these lectures to consider each point in sufficient detail to give a fair idea of the proposed system, from the point of view of a military engineer.

It should be understood at the outset that the defence of each important locality forms a study in itself. Nature has nowhere given us sites combining every desirable feature. The Engineer must avail himself of every natural advantage to the utmost, and must deal with natural defects in such a manner as to secure the maximum of strength at the minimum of cost.

This mode of approaching the subject reveals the base metal of which many theories of defence are constructed. One savant informs us that inexpensive submarine mines, easily improvised, are sufficient to close any harbor; another proposes movable torpedoes under control from the shore, or from armored rafts at anchor, as the needful panacea; another simply advocates a line of turrets, armed with modern high-power guns; another finds a perfect defence in a few disappearing guns fired from pits; another would trust to a swarm of torpedo-boats of the approved type; while another pins his faith

solely upon a fleet of armored ships of war. The truth is, such crude assertions stamp the utterer as a military quack. All of these devices, and others, find useful applications; but as soon as a serious study of our harbors is made it becomes apparent that there are locations where, so far from being sufficient, each of them in turn is quite inapplicable. There is no medicine which will cure all the ills to which flesh is heir; and the same is eminently true of an exposed sea-coast. To-day a satisfactory solution can in general be secured only by a complex combination of many elements, varying according to locality to an extent which forbids any summary not couched in the most comprehensive terms. Each individual case must be discussed on its own merits.

In general, an important seaport well defended implies: (1) the effective obstruction of all water approaches against the enemy, leaving free entrance and exit for our own vessels; (2) protection for these obstructions, and security for their operators and their flanking guns against escalade by boat parties; (3) so heavy a fire of modern high-power guns and mortars over all the approaches as to defy the most powerful armored fleet able to operate in the channels leading to these auxiliary defences; (4) a heavy flanking fire of medium and small projectiles over the obstructed zone; (5) provision for offensive returns against armored counterminers; (6) the power of illuminating the obstructions by night, so far as this is physically possible; (7) a swarm of torpedo-boats which, safe behind the barrier, are always ready to sally out and carry the war to the enemy's fleet when favorable opportunities occur.

Harbors of minor importance may be sufficiently defended upon less elaborate systems; but at the ports which the Fortification Board of 1886 reported

as "most urgently requiring defences" it would be criminal to neglect any of those named.

The first matters for consideration in deciding how any particular position shall be fortified are the calibres and numbers of the heavy guns needful to overpower the enemy's fire. These will be determined in accordance with our estimate of what he can bring to the attack, and what tactics will probably be adopted in making it.

I naturally feel some diffidence in discussing this branch of my subject before Naval experts; but as the question is a vital one for Army engineers, I shall undertake the task, hoping to receive candid criticism as to any points concerning which my conclusions may appear to be at fault.

### PROBABLE NATURE OF THE ATTACK.

The calibre of the land guns must be sufficient to pierce the armor of the enemy at a two-mile range, and to compete with his artillery on at least equal terms. His possible armament and armor are both fixed by the available depth of water in the channel of approach. Since the guns of most modern ships will pierce the armor they carry at considerable ranges, a rough estimate of what calibres we should provide may be formed by studying the armament of modern ships in connection with their draught and the depth of water in the channel to be defended.

**Needful Calibres.**—Thus, taking the British Navy as an example, the *Benbow*, *Renown*, and *Sanspareil* each carry two 110-ton B. L. guns, with from ten to thirteen 6-inch or larger high-power guns. They all draw 27 feet. No vessel with a less draught is now armed with 110-ton guns. The *Collingwood*, *Conqueror*, *Hero*, *Colossus*, and *Edinburgh* each carry either four or two 12-inch 43-ton guns, with

four, five, or six high-power 6-inch guns; and the *Inflexible*, four 16-inch 80-ton guns. Their draught ranges from 24 feet to 26 feet. The belted cruisers *Orlando*, *Undaunted*, *Australia*, *Narcissus*, and *Galatea* each carry two 9.2-inch 18-ton guns, and ten high-power 6-inch guns. Their draught is 22½ feet. As a rule no armored ships draw less than 20 feet, except the so-called Coast Defenders, which draw about 18 feet; but unarmored cruisers drawing only 16 feet could, in the present condition of our sea-coast armament, work great destruction at ranges where our guns would be powerless to reply. This class carries about 10 guns, varying between 9 inches and 6 inches in calibre; and a swarm of gunboats drawing less than 16 feet carry muzzle-loading 10-inch 18-ton guns.

No discussion of the power of these guns is needful here; I will only recall that their muzzle energies are approximately as follows:

That of the 16¼-inch 110-ton B. L. gun is 57 000 foot-tons.

That of the 16-inch 80-ton M. L. gun is 30 000 foot-tons.

That of the 12-inch 46-ton B. L. gun is 24 000 foot-tons.

That of the 12-inch 43-ton B. L. gun is 15 000 foot-tons.

That of the 9.2-inch 18-ton B. L. gun is 9 000 foot-tons.

That of the 10-inch 18-ton M. L. gun is 5 000 foot-tons.

That of the 6-inch 4-ton B. L. gun is 2 500 foot-tons.

The estimate to be placed upon the offensive power of these guns will of course depend upon the nature of the proposed works; for example, a 6-inch gun, little to be feared by a turret or an armored

casemate, might by its rapidity of fire be more formidable against an exposed barbette than even a 100-ton gun. In such cases shrapnel-fire becomes specially dangerous. Its effect is terrible, provided the projectile be *exploded at exactly the right place;* fortunately for open barbettes, precision of fire is difficult to secure on shipboard, and no perfect time-fuse exists.

Another element of the armament of modern ships must not be forgotten—the rapid-firing and machine guns. Their record at Alexandria was a poor one, but improvements are constantly making and they will certainly be brought against forts. The best defence is shoal water or submarine mines, which forbid approach within a thousand or twelve hundred yards' range; but when it is not possible to secure this advantage, guns on low sites, without cover during loading, must be regarded as of little value.

After studying the map of the entrance to be defended, in connection with lists of war-ships, which for all navies are easily accessible, the engineer can form a fair estimate of the calibres of the guns likely to be brought against him. Two points should not be forgotten: (1) Coast Defenders of comparatively little draught can carry the largest modern guns, and, although they would not be allowed to leave their regular posts of duty in a war with a formidable maritime power, they may be expected on our shores for many years to come; and (2) the moral effect of a few land guns of larger calibre than any carried by the fleet is very great. The influence of General Totten was powerfully exerted to secure the introduction of the 15-inch S. B. gun when that was supposed to be quite beyond the ability of ships to carry; the "largest gun possible" is a time-honored maxim with us, and I think the projects of the Corps of Engineers for our chief harbors will always provide for

a few of the most powerful guns which the genius of the age can fabricate successfully.

As stated above, our largest guns should at least be able to pierce the armor of the enemy at a two-mile range. This limit is adopted, partly because ships must approach to that distance to seriously annoy land guns properly mounted; partly because, with ships and forts more or less shrouded in smoke, precision of fire on our part is not to be expected at longer ranges; and partly because the area of the ship protected by her heaviest armor forms but a small per cent. of that exposed to our blows, and she may receive great injury from shots powerless to pierce her at the water-line.

**Number of Guns.**—The next point for consideration is the number of the guns likely to be brought against the port under study, by the most powerful enemy. The number which a single vessel of each class carries has already been noted; the present question is therefore restricted to the local problem of how many ships can be placed in position. For ports of the first class the basis of the estimate should be the full strength of possible attack; for ports of minor importance the Engineer will be guided by his judgment as to the size of the fleet likely to be detached for the purpose.

The determination of the length of the front of attack is a simple matter of map and dividers. Draw circles with radii varying from one to three miles, the centre being the fort under consideration, and note the lengths which fall upon water of sufficient depth and otherwise suitable for occupation by warships. The probable distance and the maximum development of the attack can thus be estimated with precision.

How near together the ships can be safely manœuvred will depend upon the strength of the current

and the nature of the channel, whether clear or obstructed by shoals, reefs, or suspected torpedoes. At Alexandria, where there was no need of crowding, about four ships occupied one mile. At Charleston, on April 7, 1863, the monitors in a difficult channel formed at intervals of "one cable length," or at the rate of about eight monitors per mile. At the attack on Fort Fisher on December 24–25, 1864, as well as that of January 13, 1865, the favorable position and calm weather offered exceptionally advantageous conditions to the fleet. The monitors were ordered to be anchored "not more than one length apart." The diagram accompanying Admiral Porter's official report of the final attack indicates that the first line (14 vessels) occupied a development of three-quarters of a mile; the second line (12 vessels) a development of three-quarters of a mile; and the third line (14 vessels) a development of one mile. The diagram of the December attack (which formed part of the official order for the engagement) does not materially differ in respect to length of development. The Admiral evidently designed to deploy his vessels at the rate of about fifteen to the mile.

These facts, I think, warrant the conclusion that the larger ships of war of to-day, under the most favorable conditions, may be expected to deploy in a single line at the rate of about ten to the mile, but that in a contracted and unfavorable channel not more than five of them would be likely to make the attempt. Indeed, some individual vessels are claimed to require a mile in which to manœuvre with safety to their neighbors. In fine, my studies induce the belief that, allowing to each vessel six effective guns of calibres varying from six inches upwards, according to her draught, we must anticipate a possible fire at the rate of thirty to sixty guns per mile of available development, depending upon the nature of the site.

The next point for consideration is the old and much-mooted question of relative efficiency between land guns and those mounted on shipboard. This question is open to intelligent differences of opinion, but, as the Engineer must commit himself to some definite estimate upon which to regulate the armament, I will state my own opinion, with some of the grounds upon which it is based.

**Guns Ashore and Guns Afloat.**—Formerly it was a maxim accepted by French engineers that one gun on shore was able, when properly mounted and served, to contend successfully with from eight to thirty on shipboard. This rule, derived from experience in such contests in olden times, was verified in the naval attack on Sebastopol, where "an earthen battery mounting only five guns, but placed on the cliff at an elevation of 100 feet, inflicted grievous injury on four powerful English ships of war, and actually disabled two of them, without itself having a gun dismounted and without losing even one man." But the rule was founded on conditions no longer existing. The ship guns of that period were small in calibre; were crowded closely together; were covered by bulwarks of oak, which, when struck by such projectiles as were used in coast batteries, afforded little protection; the ship was soon buried in smoke, which prevented the scores of gunners either from seeing how to aim or from being guided with any precision by orders from aloft; and, lastly, the armament was not readily brought to bear by reason of the unwieldy nature of the ship, which floated at the mercy of baffling winds and shifting currents, with her masts and sails exposed to destruction by a single lucky shot.

A modern duel between ships and forts is fought under very different conditions. The ships are more or less protected by armor in all vital parts; the

motive power, deep under water and carefully withdrawn, by the mode of manœuvring, from direct fire, is comparatively little exposed to injury; the guns are much fewer in number, and the smoke, although still a serious cause of inaccuracy of aim, will hardly form the impenetrable veil which hung about the old three-decker in action, and its evil effects can be more easily counteracted; moreover, the reduced size of the crews, and the protective armor (if the latter be sufficiently substantial for its work), will reduce casualties, and, leaving torpedoes out of the question, the hideous carnage of old naval contests will no longer appall the crew.

On the other hand, it must not be forgotten that the risk of injury when struck by an effective modern projectile is far greater for the ship than for the land battery. The latter may be disfigured by huge craters in the parapet, a few men may be killed, and a few guns may be dismounted, but so long as the magazines are secure no overwhelming disaster is to be feared. But one projectile which has forced its way into the complex mechanism covered by the armor plating of the ship may annihilate, at a single blow, the offensive power of an *Italia*, of an *Inflexible*, or of a *Trafalgar*. Moreover, the ship fires from an unstable deck, at varying and uncertain distances, and always more or less annoyed by the smoke of her own guns; the land battery, aided by the modern system of position-finding, is comparatively unaffected by smoke and can direct its fire with greater precision than the ship, and with vastly greater certainty than in the days gone by.

One question formerly stoutly contested has been practically answered so many times in late years that there is no longer any difference of opinion upon the subject: every one now admits that a fleet can force a passage past a line of batteries of equal or even of

superior armament, provided the channel be unobstructed. Hence in studying recent experience we may leave this class of operations entirely out of consideration, and confine our attention exclusively to instances of pitched battles between armored ships and forts. Combats of this kind are inevitable when the channel is obstructed by mines properly defended; and I shall ask your attention to a few instances which throw light on the problem, although it must be admitted that experience is still lacking on which to formulate definite rules—if, indeed, it will ever be possible to formulate rules where so great variations exist in the protection afforded by different types of armored ships and by different modes of mounting and protecting land guns. Still, experience is the only safe guide, and use should be made of all that is available.

On May 15, 1862, an earthen battery situated on Drewry's Bluff about 100 feet above James River, and without bomb-proof cover, was attacked by two iron-clads, the *Galena* and the *Monitor*, and by three wooden vessels, the *Aroostook*, the *Port Royal*, and the *Naugatuck*. The iron clads anchored at from 600 to 1 000 yards range, where a double pile obstruction, reinforced by hulks, prevented a nearer approach; the wooden vessels anchored about 1 300 yards below. After fighting for about three and a quarter hours the fleet was repulsed; the *Galena* had expended nearly all her ammunition and had suffered severely, being hulled several times. The *Monitor* and apparently the wooden vessels were not seriously injured; but Lieut.-Commander Jeffers, commanding the *Monitor*, reported: "So long as our vessels kept up a rapid fire they rarely fired in return, but the moment our fire slackened they remanned their guns. It was impossible to reduce such works, except by the aid of a land force."

The armament of the *Galena* consisted of 9-inch Dahlgren smooth-bores and Parrott rifles; the *Monitor* carried two 15-inch guns; the armament of the wooden vessels is not stated in the official reports.

When Fort Drewry was captured, in 1865, the water-bearing guns consisted of one 7-inch Brooke rifle, with six 10-inch and three 8-inch Rodman smooth-bores. I was personally informed by Major Drewry, who had commanded in the action of May 15, 1862, that at that date he had only three Rodman smooth-bores in position, the others having been added subsequently.

This was, I believe, the first decisive contest between our armor-clad vessels and a land battery. Although the result was a disappointment, and the vessels were repulsed with loss by a greatly inferior force, it must not be forgotten that the trial took place under conditions which gave many advantages to the land forces—the narrowness of the river even permitting them to annoy the fleet with musketry.

The next typical pitched battle between guns ashore and guns afloat took place at Fort Sumter on April 7, 1863. The day was calm and all the conditions were favorable to the fleet.

Fort Sumter at that date consisted of an unfinished masonry work having a single tier of casemates, strengthened by such means as the Confederates had found practicable after its occupation. The masonry was largely shell concrete faced with brick; the scarp was 8 feet thick (5 feet in front of the recess arch and 11 feet at the piers). The site was a small artificial island.

The armament which repulsed the attack of Admiral Dupont was mounted in Fort Sumter, Fort Moultrie, and in the batteries on Sullivan's Island. The Confederate official report gives the following statement of the guns and mortars used in the battle:

GUNS AND MORTARS IN USE ON APRIL 7, 1863.

| FORT OR BATTERY. | 10-inch Columbiads. | 9-inch Dahlgrens. | 7-inch Brookes. | 8-inch Columbiads. | 42-pounder, rifled. | 32-pounder, rifled. | 32-pounder, smooth. | 10-inch Mortars. | Grand total. |
|---|---|---|---|---|---|---|---|---|---|
| Fort Sumter ....... | 4 | 2 | 2 | 8 | 7 | 1 | 13 | 7 | 44 |
| Fort Moultrie...... | .. | .. | .. | 9 | .. | 5 | 5 | 2 | 21 |
| Battery Bee ........ | 5 | . | .. | 1 | .. | .. | .. | .. | 6 |
| Battery Beauregard.. | .. | .. | .. | 1 | .. | 1 | .. | .. | 2 |
| Cummings Point.... | 1 | 1 | .. | .. | .. | .. | .. | .. | 2 |
| Battery Wagner..... | .. | .. | .. | .. | .. | 1 | .. | .. | 1 |
| Total........ | 10 | 3 | 2 | 19 | 7 | 8 | 18 | 9 | 76 |

Fort Sumter fired 831 rounds; Fort Moultrie, 868 rounds; Battery Bee, 283 rounds; Battery Beauregard, 157 rounds; Cummings Point, 66 rounds; Battery Wagner, 22 rounds; total, 2 227 rounds. In all 21 093 pounds of powder were used.

The fleet consisted of the *New Ironsides*, the *Keokuk*, and seven monitors. Twenty-three guns were used in the action: seven 15-inch Dahlgrens, fourteen 11-inch Dahlgrens, and two 150-pounder rifles. One hundred and thirty-nine shots were fired by the fleet (124 of them at Fort Sumter). The 15-inch guns were charged with 35 pounds of powder, the 11-inch guns with 20 pounds, and the 150-pounders with 16 pounds.

Admiral Dupont reported the range of the monitors as from 550 to 800 yards, that of the *Ironsides* being not less than 1 000 yards; his ordnance officer, Lieut. A. S. Mackenzie, reports the ranges as from 550 to 2 100 yards; the Confederate engineers give

them as from 900 to 1 500 yards, averaging 1 200 yards.

The engagement lasted two and one-half hours. As to the result, Admiral Dahlgren reported: "No ship had been exposed to the severest fire of the enemy over forty minutes, and yet in that brief period five of the iron-clads were wholly or partially disabled; disabled, too, in that which was most essential to our success—I mean in their armament or power of inflicting injury by their guns. . . . The other iron-clads (2 out of 7), though struck many times severely, were still able to use their guns, but I am convinced that in all probability in another thirty minutes they, too, would have been likewise disabled."

The official reports of the captains commanding the iron-clads indicate that the fleet, exclusive of the *New Ironsides*, received 346 hits. The *New Ironsides* was struck several times, but the exact number appears not to have been reported. The *Keokuk* was sunk, where her guns were subsequently secured by the Confederates. One man was killed and at least twenty-two men were wounded on shipboard during the action.

Upon the Confederate side, General Beauregard states: "Not more than 34 shots took effect on the walls of Fort Sumter." "Fort Moultrie and other batteries were not touched in a way to be considered." The injuries to Fort Sumter were by no means disabling, and the total casualties on land were three men killed by the accidental explosion of an ammunition-chest, and eleven men wounded—five of them by the same accident.

The next conspicuous duel between armored ships and forts was at Fort Fisher, North Carolina. This fort had a water-front and a land-front, both consisting of substantial sand batteries; the land-front had

an oblique fire upon the sea. The work was well provided with traverses and bomb-proofs, but the former were so conspicuous that they marked the gun positions with great distinctness. The site was a low, sandy point between the ocean and Cape Fear River. The offing afforded unlimited development to the fleet.

Carrying out the plan of a co-operative attack in aid of the land forces, Admiral Porter ordered his monitors to anchor at a range of about 800 yards, and his wooden vessels in three lines at from 1 100 to 1 800 yards. The former were to fire deliberately upon the land-front (from within a dead angle where the enemy could reply only at great disadvantage) in order to prepare the way for an assault; the latter were to maintain so terrific a storm of shot and shell over the fort as to prevent the enemy from serving his guns. These tactics were successful, and the Confederates were soon driven to take temporary refuge in their bomb-proofs.

Immediately after the capture of the fort on January 15, 1865, I personally made an inventory of the armament, with notes as to its condition. The following were the water-bearing guns: On the land front, one 10-inch Rodman, five 8-inch Rodmans, five old 32-pounders, one old 24-pounder, seven 6.4-inch rifles, one 4.2-inch rifle; total, 20 guns. On the water-front, nine 10-inch Rodmans, four 8-inch Rodmans, two 8-inch rifles, two 7-inch rifles, five 6.4-inch rifles; total, 22 guns. The grand total which could have been used against the fleet was 42 guns. Of these, eight guns and eight carriages (16 in all) were disabled on the land-front, and one gun on the water-front (it evidently had burst in action). This statement includes all injuries by direct impact of shot, or by destruction of carriages, or by the piling of sand in front of the guns; they represent the whole

damage effected by one of the most tremendous bombardments of modern times directed against an open barbette battery on a low site.

The following was the effective armament of the fleet, as furnished to me by the Bureau of Ordnance, Navy Department. It includes all the pivot guns and half the broadside guns of the vessels in action, excluding the small bronze guns as of no value for such service: ten 15-inch Dahlgrens, 20 11-inch Dahlgrens, two 10 inch Dahlgrens, one hundred and thirty-four 9-inch Dahlgrens, eighteen 8-inch Dahlgrens, sixteen 32-pounders, eight 8-inch Parrott rifles, twenty-four 100-pounder Parrott rifles, two 60-pounder Parrotts, two 50-pounder Dahlgrens, twenty-seven 30-pounder Parrotts, twelve 20-pounder Parrotts, making a total of 275 guns of all calibres used against the land defences.

This bombardment silenced the fire of the fort and enabled an assault to be delivered without the preliminary operations of a siege—an assistance of the most important character; but that the damage to the works should be as unimportant as it actually was, seemed at the time almost incredible to the eyewitnesses. If the garrison had not been provided with ample bomb-proofs, a surrender might probably have occurred; but, as it was, the men took shelter until the fire slackened to favor the assault, and then they exhibited anything but demoralization. Still, it must not be forgotten that such a result to-day would be decisive in favor of an attack to force a passage; for unless the land guns can be served continuously the flanking arrangements will be destroyed, and the mines will be removed with but little risk.

These three examples, concerning which all the essential facts are known, have been selected as typical contests between guns ashore and guns afloat at

the beginning of the era of armor and of heavy guns on shipboard. They certainly prove that our iron-clad fleet could not contend with any chance of success against an equal, or even against a very inferior, land armament.

The same was true at that epoch in Europe, as appears from the result of the attack of the Italian fleet upon the island of Lissa in July, 1866. Although full data respecting this two-day engagement are lacking, enough is known to justify the claim of the Austrians "of having driven back the Italian iron-clad ships, incapable of resisting the fire of the forts which command the harbor." Just as a third attack was about to be made, including a landing of troops to storm the works, the arrival of the Austrian fleet terminated the attempt.

The land works consisted of masonry forts and earthen batteries, which appear to have usually had high sites. They were distributed among three harbors, and "the whole of the defence presented a front of nearly 100 guns." The latter were all of an old type, of which the largest were smooth-bores throwing solid shot weighing 66 pounds, and rifles throwing elongated shot weighing 60 pounds.

The armored fleet consisted of 12 ships, carrying 248 guns. Their armament "contained all the latest improvements which the modern art of war had up to that date invented." There were also 8 unarmored ships carrying 360 guns, and 16 despatch-boats.

The bombardment of Alexandria affords the only example available for testing more recent progress, and even that fails to exhibit what the latest type of guns can accomplish against land batteries.

The forts at Alexandria were mostly low barbette batteries, with a few old masonry works still less defensible against modern attack. The garrison was demoralized by being in rebellion against its own

government, which was supported by the hostile fleet. The only circumstance in favor of the rebels was the possession of a few Armstrong guns.

On the northern line there were 20 Armstrong M. L. rifles (four 10-inch, nine 9-inch, five 8-inch, and two 7-inch), thirteen 40-pounder Armstrong B. L. rifles, and 62 smooth-bores which were little used. On the inner line there were seven Armstrong M. L. rifles (one 10-inch, one 9-inch, and five 8-inch), with one 40-pounder Armstrong B. L. rifle, and 76 smooth-bores which were little used.

The working broadside of the offshore squadron opposed to the northern line the fire of 26 M. L. rifles (two 16-inch 81-tons, one 12-inch 25-tons, fifteen 10-inch 18-tons, two 9-inch 12-tons, and six 8-inch 9-tons). These were supplemented later by three more of 25 tons, two of 18 tons, and two of 81 tons.

The working broadside of the inshore squadron employed the following heavy guns, all muzzle-loading rifles: four 12-inch of 25 tons, five 9-inch of 12 tons, and four 8-inch of 9 tons; total, 13 guns.

In Captain Goodrich's Report, from which these data are extracted, is a table of numerical ratios showing "the phases which the engagement either assumed or might have been made to assume." It is:

| | |
|---|---|
| Fort Pharos........ | 4 land to 33 ship (actual). |
| Fort Adda....... | 5 land to 28 or 33 ship (actual). |
| Ras-el-Tin Lines.. | 7 land to 26 ship. |
| Light-house Fort. | 4 land to 26 ship. |
| Fort Mex........ | 5 land to 14 or 16 ship (actual). |

Taking into consideration the relative calibres as well as numbers, it is plain that this action affords no fair comparison between the fire of guns on land and those on shipboard; but it has value as a test of the effect of modern guns on batteries of the kind engaged. Three thousand one hundred and ninety-

eight rounds, of which 1 731 were 7 inches and upward in calibre, were fired by the fleet. Captain Goodrich writes: "To the unprejudiced observer the most striking characteristics of the bombardment are, without doubt, the excessive apparent and the slight real damage done to the fortifications. . . ." "The forts at Alexandria were badly bruised, but the more modern parapets were not seriously harmed. In the generality of cases the real damage they sustained could have been easily repaired in a single night. If the bombardment was directed against the forts in this their defensive capacity, it must be pronounced a failure. If its object was the dismounting of the new rifled guns, it must be conceded that such results as attended the work of the inshore squadron (only one gun of this type being seriously affected), or even such as were achieved by the offshore squadron (less than one-half being permanently disabled), do not justify the verdict of success."

The action at Alexandria, rightly or wrongly, has certainly tended to reduce the estimate lately entertained by engineers as to the accuracy of fire to be expected from shrapnel and machine guns on modern ships of war—the peace practice at Inchkeith notwithstanding. Although siege howitzers on land have proved their ability to breach concealed scarps and search out nooks and corners of fortresses with showers of descending shrapnel-balls, it now appears that no such practice is to be apprehended from vessels. Although machine and rapid-firing guns are murderous at suitable ranges on land, their fire proved to be far less terrible from the gunboats. Moreover, this fire can be neutralized by forbidding an approach to within less than 1 000 yards. In addition, it has been practically learned that high-power guns, with their flat trajectories, are unfavorable for shrapnel-fire against earth-works. The spread of the balls is be-

lieved to be often less than five degrees, and much of the effect depends on obtaining a rapid fall in the shell itself before explosion. General Sir Andrew Clarke, R. E., late Inspector-General of Fortifications, sums up a recent discussion of the subject with this language: "As regards searching effect, ships are now in a worse position than they were fifty years ago, and when re-armed with new guns their power will in this respect be still further diminished." He also states: "At Alexandria the fleet carried about seventy 1-inch 4-barrel Nordenfelts and expended more than 16 000 bullets. The expenditure of Gatling ammunition was only 7 000 rounds, and of Martini bullets 10 000. As to the results obtained opinions differed. It is submitted, however, that the number of hits on the guns and carriages of the defence may fairly be taken to afford some indication of those results. The hit of a Nordenfelt bullet on iron is generally unmistakable, but it is evidently possible that grazes at a very acute angle might have escaped observation. The total number of hits on guns and carriages was seven, and even this moderate number requires qualification."

I think, after this review of the best data upon the subject, no one will advocate a fixed ratio of comparison between the efficiency of guns ashore and guns afloat. The Engineer must carefully consider the question for his local problem and make his own estimate, taking into account the natural advantages and disadvantages of the position, and how far his art can be applied to increase the relative power of the land armament. One consideration must not be overlooked for a position of first-class importance, especially when the approaches are unfavorable to the fleet. The enemy may not be able to bring all his force to bear at the same time, but his reserves may be able to supply losses and maintain the attack with unbroken

vigor; while the land batteries, having no reserves, will become less and less able to meet it as their guns become dismounted.

Personally, while according a relatively higher efficiency to naval armaments as compared with land guns than was warranted by experience before recent improvements, I am convinced that ship guns can never hope to contend with similar land guns on anything like equal terms when the latter are properly placed in position and properly served. In fine, I think engineers would agree that for a port of first-class importance the armament should never be allowed to fall below that of the enemy in calibre, and that in number of guns we should rarely mount less than half of what can be deployed against the works in line of battle. With such an armament, well disposed upon a favorable site, and well served, I should have no fear of the result, and indeed one much weaker would have a fair chance for success.

It only remains to consider how a land position is likely to be attacked by a fleet.

**Naval Tactics against Forts.**—At Port Royal, in November, 1862, Admiral Dupont captured the land defences (Forts Walker and Beauregard) by a system of tactics which consisted in keeping his fleet (unarmored) in constant motion upon an elliptical curve which brought the ships within a range of about half a mile of the forts in passing. These forts, armed with 35 small guns, only two being rifled, were earthen batteries of slight command and ill-fitted to endure so powerful an attack as that of his squadron. Still, at that date these tactics were highly admired, and were even claimed by some enthusiasts to mark a new era in such operations.

Similar tactics were tried at Alexandria in 1882, the speed being about five miles per hour, but without a satisfactory result. Captain Goodrich states:

"The outside squadron having tried both modes of attack, under weigh and at anchor, definitely solved one important problem. There remains no possible doubt that ships engaging forts not superior to them in force will gain more in accuracy of fire by anchoring than in safety by keeping under way." These views accord with statements of Royal Engineer officers and with my own belief; for I think that land guns will hereafter be so protected in positions of importance that they will have little to fear from the inaccurate practice inseparable from motion.

Accepting, then, as a maxim that a first-class naval attack upon a well-fortified position will be made at anchor, or at any rate from fixed buoys to indicate the precise range to the gunners, the defence, aided by the modern system of position-finding, can count upon all the advantages resulting from superior stability of platform, freedom from the annoyance of smoke, and a better knowledge of the range.

But what ranges will ships select when the channel allows a choice? The preponderance of professional opinion is that it will be as short as the power of the land guns will permit. If that power be insufficient to penetrate the armor, ships will approach very closely to increase their precision of fire as much as possible. Their targets are guns and magazines, and all shots that fail to attain them are thrown away, although great apparent damage may result to earthen parapets and to masonry walls.

At Lissa the fleet forced the fighting, ranges of 300 and 400 metres being mentioned in the report.

At Alexandria the outside squadron began the action at a minimum range of about 1 500 yards. Of the inshore squadron the flagship was anchored at 1 300 yards, while the *Penelope* drifted several times broadside on from that distance to 700 yards. The *Inflexible* and *Téméraire* fired at very much greater

distances—between 3 000 and 4 000 yards. These long ranges were criticised by Captain Goodrich as "needlessly great." He states: "The outside vessels could have gone to within 1 000 yards on the northwest side of the Light-house fort and 800 yards abreast the Ras-el-Tin lines; to within 500 yards of Fort Adda and 200 yards of Fort Pharos. Along the southern line the ships could easily have gotten within 400 yards of all the batteries. This would have prevented the *Téméraire* from shelling Mex, but it is believed that the gain would have outbalanced the loss. It can hardly be doubted that the boldness of this move would have been rewarded by the speedier and more extensive dismounting of the guns, which was confessedly the chief object of the attack. Shrapnel and canister from a portion of the ships' batteries, supplemented by the machine guns at a more appropriate range than that originally adopted, would have prevented return fire from the shore; and the remainder could have been concentrated on each gun in the forts in succession until bowled over. Close range and a stable platform, however, are necessary for such refinement of practice."

I think there can be little doubt that such considerations will commend themselves to Naval Commanders; and they must be met by at least a few guns of the largest calibre, and by outlying submarine mines where nature permits too close an approach to the works. A shoal in the near front is a great merit in a position for a battery. The ship must necessarily fight under disadvantages as to precision of fire, and it is the business of the Engineer to secure the full benefit of this advantage by forcing an action at long range.

If this be desirable for horizontal fire, it is absolutely essential for vertical fire. With mortars the

force of impact depends upon the fall of the projectile, which fall is a direct function of the range; hence with this class of ordnance very short ranges are to be forbidden to the enemy at any cost.

To sum up these conclusions as to the probable nature of an attack by a modern fleet upon a sea-coast fortress of the first class, I am disposed to believe: (1) that we should be prepared to meet the largest calibres which the draught of water in the channel will admit; (2) that from five to ten ships, carrying from thirty to sixty guns of six-inch calibre and upward, should be estimated for each mile of the line of battle —the character of the approaches determining the precise number; (3) that the attack will be made at anchor, or at least from fixed buoys, in order to increase the precision of fire; and (4) that it will be made at as close quarters as possible. The Engineers should provide for a land armament at least equal in calibre, and perhaps half as large in number of guns, as that which can be deployed against the works. All approach to within less than 1 000 yards must be forbidden, use being made of submarine mines if deep water renders them necessary for this purpose. With a reasonably favorable site, well occupied, I consider that such preparations would probably deter attack and would certainly give large odds in favor of the land defences.

# Lecture II.

## ECONOMY IN COAST DEFENCE.

Limit of judicious outlay—Economic value of different elements ; general analysis ; case of non-disappearing barbette mounting; case of the King mounting for 50-ton 12-inch rifle ; case of the Duane lift; case of an armored casemate; case of a revolving turret ; general conclusions.

Before proceeding to consider details it will be well to discuss with some care the fundamental basis upon which they all rest. Are outlays for coast defence demanded by the needs of the country ; and, if so, how large an amount should be asked of Congress? How far are projects for coast defence to be influenced by the question of expenditure?

### LIMIT OF JUDICIOUS OUTLAY.

From one point of view expenditures for seacoast defences should be regarded simply as a necessary business outlay entailed by the possession of wealth, and should be governed by the usual rules of insurance, so far as they can be applied. A citizen of New York pays a certain percentage of his property towards the support of a fire department, because he is convinced that the outlay is demanded by true economy as a protection against loss by fire ; he pays another tax to maintain a police department to afford security against individual violence and robbery ; he contributes his assessments in support of the National Guard, because he knows that mobs are a danger to life and property which timely precautions alone can control ; finally, not satisfied with

these precautions, his business instincts teach him to pay large sums for insurance, to reimburse him for losses which may probably overtake him in spite of all his forethought. It seems amazing, to one who has reflected upon the subject, that this same man appears to forget that war, liable at any time to occur, may result either in the burning of his property under circumstances which will cripple the fire department, disperse the police and National Guard, and bankrupt the insurance companies, or else will subject him to enormous impositions to purchase exemption from utter destruction. Surely all history proves that this danger is real, and should arouse public sentiment to demand that the lethargy which for a dozen years has paralyzed us shall cease, and that the general government, without further delay, shall attend to its duty of providing for the national defence.

It must not be overlooked that, in some important particulars, funds invested in sea-coast fortresses are far more advantageous than ordinary insurance. Thus, instead of merely distributing the loss among many individuals, they prevent it altogether. Moreover, large continuous outlays are not required. The works are imperishable and the annual premiums are therefore small. A port once provided with adequate defences remains in security until new progress in the art of war demands modifications. In a word, their utility is as permanent as anything human.

But, it may be asked, what has this problem in political economy to do with the duty of the military engineer? I answer, Much. He should regulate his plans and estimates upon the same principles which determine the size of the fire department, the strength of the police force, and the organization of the National Guard. His problem is more complex, because the elements are more uncertain, the field is

broader, and constructive damages constitute a larger element; but, after all is said, the matter reduces itself to dollars and cents. If, ignoring the question of cost, the engineer demands a larger outlay than business principles will warrant, he rightly fails to command the confidence of those whose duty it is to scrutinize the necessity for expenditures before voting appropriations.

When preparing a project for defence the first matter for consideration is, therefore, what sum can judiciously be expended. This by no means signifies exact figures, like those for the cost of a mass of concrete or of an iron shield; there are many elements to be considered, some of which can be measured by the gold standard, while others can hardly be so gauged. As an example of the first class, the port may contain a great city, and the assessed valuations for real estate and personal property are always accessible, while fair estimates of the value of exempt and untaxed real estate and personal property may usually be obtained with some degree of exactitude. If a hostile fleet succeeds in forcing its way into the harbor, the property which lies at its mercy will either be destroyed or will be ransomed at a price which may range, according to circumstances, even up to a full cash valuation of all property subject to destruction. This valuation, of course, will exclude the cost of land, of water-works, of gas-mains, of rolling stock of railways, of bonds and specie, and of all other non-destructible or removable property. What is needed, therefore, by the engineer in his estimates for this class of probable damages is a fair valuation of the *total destructible property*.

When preparing a paper on Coast Defence which was read before the Military Service Institution in 1885, Captain Eugene Griffin, Corps of Engineers, corresponded with collectors and receivers of taxes,

boards of assessment, and collectors of ports, and consulted reports of Tax Departments and other official documents of a similar character, with a view to obtain a fair estimate of the destructible property exposed to an enemy in eight of the eleven ports afterward (1886) reported by the Endicott Board as "most urgently requiring fortifications or other defences." The three ports not included were the Lake ports, Hampton Roads, and Washington.

Captain Griffin presents the results of his researches in tabular form; and they convey much information useful for reference in this connection. The figures are based on valuations for the year 1884, three years ago. But the records show that during the past ten years there has been in New York City an average annual increase of $40 000 000 in the total assessment valuation for real estate and personal property. Last year this increase was $50 000 000. We should therefore accept Captain Griffin's figures as now considerably under the true values.

His grand total of destructible property for these eight ports (Portland, Boston, Newport, New York, Philadelphia, Baltimore, New Orleans, and San Francisco) is $4 529 177 244. The estimate of the cost of fortifying these same eight ports upon a liberal scale, presented by the Endicott Board (including $18 875-000 for five floating batteries and their armament, to be used at San Francisco and New Orleans), is $90 018 150, or a gross sum not quite two per cent. of the value of the destructible property now at the mercy of any maritime enemy. Extending these expenditures over a term of ten years, as is proposed, they would amount to an annual expenditure of two-tenths of one per cent. of the destructible property.

Let us now see how this compares with the premiums paid for other insurance in New York. The

City pays over $1 500 000 annually for the support of its fire department and over $6 000 000 annually for insurance against fire—aggregating, say, $7 500 000. It pays over $500 000 annually for its courts, its prisons, and the support of its criminal classes, and over $4 500 000 annually for its police department—or a total of upward of $5 000 000 as its insurance against minor disorders and robbery. The cost of the National Guard, which represents insurance against mob violence, is not less than $617 000, of which the State pays $400 000 for cost of camp-ground, pay of troops in camp, annual allowance for clothing, drills, etc.; the county contribution for rent of armories, janitors, etc., in New York and Brooklyn, is $117 000; the balance, $100 000, is the estimated private outlay of the members themselves.

The aggregate annual insurance against these three dangers, fractions included, is, say, $13 800 000. The corresponding total destructible property in 1884 was $1 855 303 043. The total annual insurance against these ordinary dangers in the City of New York is, therefore, eight-tenths of one per cent. of its destructible property, or four times the percentage proposed as an *annual expenditure for ten years* for the most important coast defences of the Nation.

The financial question, therefore, resolves itself into this: Is it or is it not judicious for the Nation to pay in ten years for protecting, during a term of many years, the property exposed to destruction in its eight principal ports, as high a premium as New York pays continuously every 2.5 years to protect itself against loss by fire, by robbery, and by violence? It would certainly appear that business principles demand such an expenditure.

But this basis for considering the matter is a very inadequate one, even from a financial point of view. The Nation is bound to supply its coasting trade

with some refuge from cruisers in case of war; and this cannot be done so long as even its chief ports are open to the enemy. The same remark is true now, and must remain so for some years, even for the Navy itself. Our navy-yards are all exposed to sudden raids. We are even debarred from seeking reprisals with our new cruisers; for, with our ports open to the enemy, we should pay in cash for every capture as soon as it was made. Precedents for this ready mode of keeping our *Alabamas* in check are not wanting; for a similar system was enforced against France during the late war, to protect bodies of German cavalry scouting through the country.

But if these interests, which can be measured in dollars and cents, demand attention by every recognized business principle, how shall we estimate the National humiliation we invite by slumbering on in our present unprotected condition, while the rest of the world is so actively awake? The stars and stripes, held aloft at so fearful a cost twenty-five years ago, are now exposed to insult by second and third-rate powers whose geographical positions, even, are hardly known to our populace. If this exposure, so well understood by Army and Navy men, were appreciated by the country at large, should we have been allowed to sink to such a condition?

I dwell upon this branch of my subject because the facts should be emphasized, (1) that there is urgent necessity for action; and (2) that engineers limit their estimates for coast defence to reasonable sums. The nation has increased so rapidly that our people still gauge their ideas of military expenditures by a scale long since outgrown. Because the sums appear large when stated in dollars and cents, the enormous interests involved are forgotten and an outcry of extravagance is raised. All that engineers demand is a fair hearing, and a discussion of a busi-

ness question upon business principles and in a business-like way.

Before quitting the subject let us, to fix ideas, attempt to consider a little more mathematically the problem what sum ($x$) the nation ought to expend annually on its fortifications—every consideration which cannot be measured by a gold standard being ignored.

Clearly this sum will be directly proportional to the value ($V$) of the property exposed to capture, and directly proportional to the average frequency of war with maritime powers, which may be expressed by the fraction $\frac{W}{P}$, in which $W$ denotes the number of years of war, and $P$ the number of years of peace, noted during a period sufficiently long to afford a fair average. The sum to be expended will be inversely proportional to the efficiency of the existing defences, which may be represented by the fraction $\frac{S}{S-S_{,}}$, in which $S$ denotes the price of an adequate system, and $S_{,}$ the part of this price already paid. The sum to be properly expended will also be inversely proportional to ($F$), a quantity representing the fear of our retaliation or of an attack by other enemies while involved with us, and the improbability of our own inauguration of war. Hence, representing by $C$ a numerical constant, we may write:

$$x = \frac{C\,V\frac{W}{P}}{\frac{S}{S-S_{,}}F} = \frac{C\;V\;W\,(S-S_{,})}{F\,P\,S}$$

From this equation it appears that $x$ can be zero; *i.e.*, that the Nation can afford to pay nothing for defences, only upon the condition that $W=0$, or that $S=S_{,}$, or that $F_{,}=\infty$; or, in other words,

when the millennium has come, or when adequate defences are completed, or when every maritime power so dreads our strength, or the hostility of its neighbors, that our wealth offers no sufficient temptation to declare war against us or to give just provocation for war on our part. But few will claim that wars have ceased, or that our defences are perfect, or that our naval power is so vast as to spread terror throughout the world. The uncertainty of the relations between the great powers was probably our salvation during the civil war; but it is a slender reed upon which to rest our only hope when our exposed wealth is measured in thousands of millions, and is increasing with wonderful rapidity from day to day. Moreover, it will be noted that this condition ($F = \infty$) implies that we have made up our minds to endure any insult or outrage rather than have recourse *ourselves* to the *ultima ratio regum.* The Monroe doctrine must be abandoned; we must see the Sandwich Islands pass under a foreign protectorate, if such be the pleasure of a commercial rival; our fisheries must be left without that protection which every government owes to its citizens; the Isthmus canal, when completed, may be used to discriminate against us, even to the extent of ruining our commercial interests, without arousing us to action; in a word, we must humble ourselves to admit that we have no rights which any nation possessed of an armored fleet is bound to respect. That the American people will ever consent to occupy a position so humiliating is a supposition not to be named. Indeed, the belligerent shrieks which are always raised by newspapers and demagogues when our foreign political horizon becomes overcast, and the excitement which stirs the better class of our population as well, afford ample evidence that even although defeat were certain, the government would never be al-

lowed to avoid a just quarrel. For these various reasons we cannot assume $F = \infty$; and therefore, logically, our sea-coast must be adequately defended.

But let us go a little further, and, by assigning fair numerical values to the quantities in this general formula, try to estimate in a very general manner what sum business principles demand shall be expended next year upon the defences of New York City. Since $S_{,}$ is practically zero, both that quantity and $S$ disappear. From Captain Griffin's researches, and the rapidly increasing wealth in the City during the past three years, $V$ may now be assumed at $2 000 000 000. One consideration, however, must not be forgotten. Although this amount represents the total property which would be the prize of a hostile fleet forcing its way into New York Harbor, and which at its option might be destroyed, a much smaller ransom might probably be accepted; because a certain percentage of this value actually carried off in gold might be more important to the captor than the forcing of a larger loss upon us. What percentage might be demanded as a ransom would depend upon the local circumstances of the case; but certainly, in view of recent similar assessments, ten per cent. ($200 000 000) must be regarded as a moderate demand.

The values of $W$ and $P$ must be derived from our actual experience as a nation. During the 111 years which have elapsed since the Declaration of Independence we have passed about nine years in actual warfare with Great Britain; and have been in such imminent danger of foreign interference during the late civil war, to say nothing of threatened hostilities with France in the latter part of the last century, and with Spain on several recent occasions, that, in prudence, say 3 years more should be added. Hence $W$ becomes 12, and $P$ becomes 99. But it may be

objected to these figures that our present strength as a nation is so much greater than it was in the earlier years of our national existence that they afford no fair indication for the future. This argument might have weight if our offensive power upon the sea had increased *pari passu* with our wealth. That form of national strength alone can be considered, since our ability to raise armies on land does not enter into the problem when confronted with an enemy across the water. Offensive power upon the ocean deters maritime attack, but exposed wealth invites it. Hence it is the ratio between these quantities at different periods of our national existence which is to be considered; and it may safely be affirmed that never before in our whole history has this ratio been more unfavorable than it is to-day.

The quantity $F$, the general character of which has already been considered, is more difficult to express numerically. Mathematically it is a ratio of which the numerator is unity and the denominator a proper fraction—*i.e.*, the denominator is zero for absolute security and unity for existing war. What value shall be assigned is a matter of judgment; but perhaps our past history affords the fairest measure. We have been engaged in actual war (not including Indian wars) about one-seventh of our national existence, and I shall therefore assume $F$ to be $\frac{1}{\frac{1}{7}} = 7$.

Making the above substitutions in the formula, and noting that from the values assumed for the several quantities $C$ becomes $\frac{1}{10}$, we have the numerical value:

$$x = \frac{0.1 \times 2\,000\,000\,000 \times 12}{7 \times 99} = \$3\,463\,178.$$

But this sum which, upon business principles, should be expended upon the defences of New York

City during the coming year, exceeds by fifty per cent. the amount recommended by the Endicott Board [$2 394 850]. Hence that Board under-estimated rather than over-estimated the business risks and necessities involved in the problem of the defence of New York, and, more generally, in that of our sea-coast and Lake frontier. That they did not ignore financial considerations is shown by the following quotation from their report:

"A comparison can now be made of the estimates for modern works with those made in 1840, when the old system of coast-defence had received considerable development and was being pressed toward completion. The population of the country at that time was 17 000 000, and the estimate of cost, including the amounts already expended, was $57 131 541, being at the rate of $3.35 per head.

"The population in 1880 was 50 000 000, and the estimate for the coast defence is $126 377 800, or at the rate of $2.52 per head.

"The valuation of property in 1880 was $43 642-000 000; that of 1840 was about $4 000 000 000, and it is to be seen that the ratio of the estimate for defences to the wealth of the country at the present time exhibits a still more favorable comparison.

"In 1840 the cost of the line-of-battle ship, then representing the most formidable means of attack against coast defences, was about $550 000, and the cost of the corresponding war-ship of the present day is about $5 000 000. While the ships have increased in cost ninefold, the estimate of the defences to resist them has increased only between two and three fold."

The present humiliating condition of the country, arising from the neglect of this subject, can hardly be expressed in more forcible language than that attributed to Hon. Robert T. Lincoln, who when Secre-

tary of War was in a position to have his attention officially directed to the matter. He is quoted as recently saying: "During my term as Secretary of War you recall there was a diplomatic difficulty with Chili. I was in trepidation for some time lest she should send an iron-clad up the coast and exact a heavy tribute—millions of dollars, in fact—from San Francisco, under threat of laying the city in ashes, which she could easily have done. Any of the great naval powers of the world could do such a thing—along our Atlantic seaboard, for instance—in case of trouble. Of course, had we entered upon war with Chili, she would have got the worst of it in the end; but it would have taken time enough to obtain a navy before we could have even begun offensive operations. In point of fact, there is much latent hostility against us among foreign nations, and it would often be easy to bring on a war. But we are not in condition for it, and all the world knows it. Hence our foreign policy lacks self-respect and a proper assertion of our nation's dignity and power. We would be at first at the mercy of foreign States in case of hostilities, and our government has to be humble in its diplomacy in consequence."

### ECONOMIC VALUE OF DIFFERENT ELEMENTS.

It is certain, for reasons which need not be discussed, that in this country appropriations will never exceed a fraction of the sums which might economically be applied in coast defence. Hence not only should estimates never cover extravagant or merely ornamental work, but the constant aim should be to provide the most effective and economical parts of the system first. In a word, funds must be applied where they will yield the quickest return in defensive strength. By following this course, and only by following this course, will the engineer be acquitted if

disasters, largely resulting from ill-judged parsimony in appropriations, should hereafter afflict the Nation.

But the ground is sometimes taken that where cost comes in conflict with the best mode of fortifying a particular site, cost must yield. The best system must be adopted, no matter at what expense. If a 16-inch gun is better than a 10-inch gun, it must be had; if a turret is superior to a lift or to a disappearing carriage, it must be built. In a word, cost is to be considered only when it becomes so enormous as to forbid any hope of obtaining the needful appropriations. In my judgment, in the present defenseless condition of the coast this is a very mistaken view of the case.

For example, suppose a million dollars were granted by Congress for beginning the work of defending New York Harbor. The construction of a turret for two 110-ton guns on the site of Fort Lafayette would not, in my judgment, be a judicious application of the money. Such a turret is needed and should be built; and if our government exhibited as much interest in Coast Defence as does Russia or Italy it would certainly be promptly built. Still, the funds could be better applied under the peculiar conditions existing here. There is no probability of our being able for some years to fabricate 110-ton guns; and until we can do so the turret has no practical value—for there is no chance that Congress will import guns from Europe. One million dollars expended in submarine mines, operating casemates, cable-shafts and galleries, mortar batteries, lifts, and disappearing-gun batteries, would produce a much quicker return, and would at least enable some defence to be made, and at a much earlier date, than if the money were sunk in the turret.

But we may go even farther, and reach the same conclusion upon the supposition that the ordnance

will be on hand ready for mounting as soon as the turret is completed. No doubt a turret at Fort Lafayette mounting two 110-ton guns would have enormous influence in deterring an attack; but thirty-two 12-inch rifled mortars, six 12-inch rifles, mounted say, one on a lift and five on disappearing carriages, behind substantial earth parapets, and an effective system of mines, with casemates, cable-galleries, etc., complete, all of which could be provided for a million dollars, would yield a better return for the investment.

I dwell upon this point because it is well worthy of consideration, and because it is probable that many officers, both of the Army and Navy, may not entirely agree with me. We see clearly what is the most powerful element, and are inclined to insist on procuring it, no matter what may be the cost. If funds were liberally provided to meet the needs of the service, there would be no question that this is the right principle; but we know to our sorrow that this is not the habit of legislators. Funds are given sparingly and, what is worse, irregularly. In my judgment they should be applied so that the aggregate defensive return shall be the greatest, even at the temporary sacrifice of some of the more expensive and powerful elements. The whole case may be put in a nutshell. Sooner or later war will surprise us, and we shall have to do the best we can with very inadequate means. This ought not to be so; but it will be so, in spite of all efforts to the contrary. Hence, in my judgment, funds should now be applied as we shall wish that they had been applied when we find ourselves compelled to fight with but few chances of success in our favor. An *Inflexible* would be a precious possession; but I think the 50 first-class torpedo-boats, which, according to the money standard, she represents, would be of more service in the

defence of our extensive sea-coast if the war-cloud were to burst to-day, or at any time within half a dozen years, and very probably, indeed, at any time within the next twenty years. I fear we shall never have the coast properly defended until another war like that of 1812 teaches our people that coast defence is a live issue. In a paper read before the Essayons Club of the Corps of Engineers, many years ago, Major W. R. King discussed this question ; and I quite agree with his conclusion that "cost is not only a proper standard of comparison in engineering matters, but to disregard it, or to speak of adopting a certain material or mode of construction regardless of cost, is simply a misapplication of terms." Our people thoroughly understand the cash standard in their private business, and we must do the same in this matter of coast defence, or some day we shall rue its neglect. If these premises are sound the conclusion is far-reaching for both services.

The problem of a new Navy is under solution by naval men. The Army problem is now before us for consideration ; and, to illustrate the principles which, in my judgment, should govern in such studies, I ask you to consider how a gross sum to be expended for the defence of New York should be allotted among different objects of expenditure ; and, to simplify this discussion, I will limit it to the very practical question, How should one million dollars be expended in purchasing and placing in position 12-inch 50-ton rifles ?

**General Analysis.**—Evidently the maximum serviceable number of guns will be obtained by placing them upon simple barbette carriages standing upon the shore, without protection, remote from each other, and with no provisions for loading other than by hand. This would represent one extreme solution. The other would be to mount one gun in all

the security and with all the facilities for rapid loading which could be obtained by expending the whole balance of the appropriation on these accessories. Between these limits what would be the most economical and hence the most judicious investment of the funds?

I shall assume three fundamental principles which, although perhaps sometimes modified by special conditions, are in general true. They are, (1) that the object to be sought is the maximum possible number of well-directed shots fired against the enemy during the engagement; (2) that the economical value of a gun-carriage and mounting is directly proportional to the number of shots it permits to be so fired, provided this number does not exceed the limit which the gun can safely endure; (3) that the economical value of an artificial protection for the gun and carriage is inversely proportional to the dangerous area through which it permits the shot of the enemy to attain essential parts of the mechanism.

In an exhaustive discussion of the problem other elements would find a place—such, for example, as diminished efficiency resulting from restricting elevation and traverse in return for cover. Practically, however, these are believed to be of so much less importance that they may be waived. Thus lifts can be arranged for an all-round fire unlimited as to elevation; a revolving turret allows a full traverse of 360 degrees, and all the elevation (15 degrees) which is of much value against shipping; the disappearing carriage affords only about 120 degrees in traverse, but is unlimited as to elevation; in fine, the armored casemate is the only form of protection now advocated which seriously restricts the field of fire. But few positions demand an all-round field; and, more generally, conditions as to the offensive elements of the

battery are so dependent on the particular site that they may be ignored in a general discussion. Locally they must be duly considered by the Engineer.

In reasoning upon such questions the use of algebraic formulæ is almost a necessity, and I shall therefore ask your indulgence for introducing the method here.

Let

$d$=duration of engagement in minutes.

$t$=minimum interval between shots which the gun will endure.

$t_{\prime}$=interval between shots, loading by hand.

$t_{\prime\prime}$=interval between shots, loading by stored power.

$a$=area of target, in square feet, presented by an unprotected gun and carriage.

$a_{\prime}$=area of target, in square feet, presented by a protected gun and carriage.

$m$=number of minutes before the enemy by his fire can disable the unprotected gun and carriage.

$m_{\prime}$=number of minutes before the enemy by his fire can disable the protected gun and carriage.

$V$=cost of a 12-inch 50-ton gun mounted without protection, on a hand-loading carriage.

$S$=funds available for purchasing and placing in position 12-inch 50-ton rifles.

$x$=number of guns that should be mounted with $S$.

$T$=maximum percentage of $V$ to be expended in increasing rapidity of fire.

$M$=maximum percentage of $V$ to be expended for cover of gun and carriage.

Considering first the matter of rapidity in loading, we have for the number of rounds fired by hand, $\frac{d}{t_{\prime}}$; and for the number of rounds fired by stored power, $\frac{d}{t_{\prime\prime}}$. The difference between these quantities

will be the number of rounds gained by improvements in loading, providing, of course, that $t_{,,}$ be not made less than $t$. Factoring this gain, one factor being the number of rounds with hand-loading, the other ($T$) will express the maximum fraction of $V$ which can economically be expended for machine-loading. Hence:

$$\frac{d}{t_{,,}} - \frac{d}{t_{,}} = \frac{d}{t_{,}} \times \frac{t_{,} - t_{,,}}{t_{,,}}$$

$$(1) \quad T = \frac{t_{,} - t_{,,}}{t_{,,}}$$

Next, considering the question of cover for the gun, by following the same course of reasoning as above we have:

$$\frac{m_{,}}{t_{,,}} - \frac{m}{t_{,,}} = \frac{m}{t_{,,}} \times \left(\frac{m_{,}}{m} - 1\right)$$

$$M = \frac{m_{,} - m}{m}$$

But since $m : m_{,} :: a_{,} : a$, the numerical value of this ratio will not be changed by writing $a_{,}$ for $m$ and $a$ for $m_{,}$. Hence:

$$M = \frac{a - a_{,}}{a_{,}}$$

But by revolving turrets, by lifts, and by disappearing gun-carriages, the gun and carriage may be removed entirely from the sight of the enemy for a greater or less time between shots. By revolving turrets and lifts its protection is thus nearly absolute when in the position of loading; and by disappearing gun-carriages it is but little less so, being then subject only to danger from shots on the rapidly descending branch of their trajectory. Let us now

introduce these elements into the calculus, and decide how much we can afford to pay for such extra protection. This may be computed, with all needful precision, by giving a coefficient to $a_{\prime}$ in the last equation. Thus, if $b$ denote the quotient of the time during which the gun is exposed between two consecutive shots by the whole time between two consecutive shots, $b\,a_{\prime}$ will represent the mean area serving as a target; and we have only to substitute $b\,a_{\prime}$ for $a_{\prime}$ in the above value for $M$, giving for this class of gun protection:

$$(2)\quad M = \frac{a - ba_{\prime}}{ba_{\prime}}$$

Strictly speaking, $b$ should be a little less than the fraction above indicated, because this mode of mounting gives the power of entirely withdrawing from danger any particular gun upon whose emplacement the enemy is concentrating his fire, and, while he is thus wasting ammunition, taking advantage of the comparative security of our other guns (against which he must have temporarily reduced his fire) to overwhelm him with deliberate practice. Since the gun has to be moved, however, this advantage will probably be offset by a small lengthening in the time between shots—*i.e.*, by a small increase in $t_{\prime\prime}$. Both these details may be neglected, because their difference is too small a quantity to be considered in an analysis so general as this.

In combining these several elements into one equation, it must be remembered that the fractional coefficients represent the *maximum percentages* of the cost of the gun and mounting to be economically expended in the improvements which the terms of the formula represent; and hence that new coefficients must be added to reduce the values thus found to the *actual percentages* necessary to secure the desired

improvements. Let $A$ and $B$ represent such coefficients, respectively, and we may write:

$$x\,V + Ax\,V\,T + Bx\,V\,M = S$$

$$(3) \quad x = \frac{S}{V\,(1 + A\,T + B\,M)}$$

Proceeding to numerical applications of these formulæ, let us first compute the largest price which can judiciously be paid for appliances for loading superior to those available in hand-work. Assuming $t$ to be 5 minutes, $t_{\prime}$ to be 10 minutes, and $t_{\prime\prime}$ to be 5 minutes, equation (1) indicates:

$$T = \frac{10-5}{5} = 1$$

That is, a sum equal to the cost of the gun mounted without cover for hand-loading, or say $70 000, may be expended to reduce the time of loading from 10 minutes to 5 minutes. The actual cost of such improved facilities would not probably exceed $20 000, liberally estimated. Hence the numerical value of $A$ (the quotient of 20 000 by 70 000) becomes, say, 0.3.

In discussing the question of cover, five kinds of mounting will be considered: the simple barbette carriage behind an earthen parapet; a King disappearing-carriage behind an earthen parapet; a lift of the pattern elaborated by General Duane; an armored casemate, and a revolving turret. To make the comparison exact it would be necessary to know the precise dimensions of the gun, of the carriage, and of the exposure with each kind of cover. I shall only attempt to make use of values closely approximate to the truth.

When a 12-inch gun is mounted without cover upon a carriage made after the old barbette centre-pintle pattern for hand-loading only, it offers a tar-

get of about 70 square feet to a direct fire from the front, and of about 175 square feet to a fire perpendicular to its flank. These areas are computed upon the assumption that shots may arrive at any angle between the horizontal and a fall of 10°; and, also, that if they pass 2 feet below the level of the traverse-rails they will disable the gun. Intentional ricochet fire is ignored as no longer probable, especially against guns on bluffs. Since the fire may come through a wide arc in front, a mean of the two areas above given, or 125 square feet, will be assumed as a fair value to represent the target presented to the enemy.

**Case of a Non-disappearing Barbette.**—A shot striking the superior slope in front of the gun ten feet or less from the interior crest would undoubtedly disable the gun. The descending branch of a trajectory having a fall of ten degrees, passing through this point, would intersect the platform near the rear traverse-wheels. The protection afforded to the gun by this mode of mounting is therefore much less than would appear at first sight. Indeed, the area of the exposed target, computed upon the assumptions above made for the unprotected gun, has still the large value of about 80 square feet. Hence, by equation (2),

$$M = \frac{125-(1\times 80)}{1\times 80} = 0.56$$

Hence \$70 000×0.56, or \$39 200, is the maximum sum which can economically be expended for this mode of mounting. The average actual cost of such a battery would probably not exceed \$20 000, showing that it is judicious to give even this insufficient protection to the gun. Indeed, on very high sites, like the bluffs bordering the Golden Gate, these figures give an exaggerated idea of the defects of the system.

The value of $B$ for this kind of mounting (20 000 divided by 39 200) is 0.51.

**Case of the King Mounting for the 50-ton 12-inch Rifle.**—The gun in its firing position exposes a target of about 80 square feet; and in its loading position, perpendicular to the parapet, a target of about 40 square feet—computed on the same principles as above.

Major King estimates that the gun can be fired with steam-power deliberately once in six minutes; but by improved machinery it could doubtless be fired once in five minutes. Assume it to be exposed in the firing position one minute, and in the loading position perpendicular to the parapet four minutes, and $ba$, becomes

$$\frac{80 + 40 \times 4}{5} = 48 \text{ square feet.}$$

And from equation (2) we have:

$$M = \frac{125 - 48}{48} = 1.60$$

Hence \$70 000×1.60=\$112 000 is the largest sum which can be paid judiciously for this mode of mounting. The actual cost of such a battery, including the extra cost of the carriage, would probably not exceed \$25 000. Hence the value of $B$ (25 000 divided by 112 000) becomes 0.22.

**Case of the Duane Lift.**—The gun in its firing position will expose a target of about 80 square feet, and in its loading position will be entirely covered. Assume it to be fired once in 5 minutes, during which it is exposed 2 minutes, then $ba$, becomes:

$$\frac{2 \times 80}{5} = 32 \text{ square feet.}$$

And from equation (2) we have:

$$M = \frac{124-32}{32} = \text{say } 2.90$$

Hence \$70 000×2.9=\$203 000 is the maximum which should be expended for this mounting. The actual extra outlay is estimated at about \$80 000; and the value of $B$ (80 000 divided by 203 000) becomes 0.40.

**Case of an Armored Casemate.**—The gun is constantly exposed, forming a target which may be estimated at 20 square feet. Hence from equation (2):

$$M = \frac{125 - 20}{20} = \text{say } 5.25$$

Hence \$70 000×5.25=\$367 500 is the maximum judicious outlay. The actual extra cost of such a mounting will probably be \$200 000. Hence for $B$ (200 000 divided by 367 500) we have 0.55.

**Case of a Revolving Turret.**—The gun will expose a target of about 20 square feet, for, say, two minutes out of five. Hence

$$ba_{,} = \frac{20 \times 2}{5} = 8;$$

and from equation (2) we have:

$$M = \frac{125 - 8}{8} = \text{say } 14.62$$

Hence \$70 000×14.62=\$1 023 400 is the maximum price which should be paid for this mounting. But the actual extra cost would probably nearly or quite equal this sum, and $B$ is therefore unity.

**General Conclusions.**—Equation (3) solved with these values exhibits the comparative results (shown in the following table) of the expenditure of one million dollars for providing 12-inch 50-ton rifles. The figures in the second column show the number of guns, firing once in five minutes and mounted as de-

signated in the first column, which can economically be placed in position; and the figures in the third column, the number of such guns which can actually be mounted. The fourth column gives the number of shots which can be fired per hour by the number of guns indicated in the third column. The fifth column exhibits the relative life accorded by the different mountings, assumed to be measured by the inverse ratio of their exposures. The sixth column contains the quotients of the products of the figures in the fourth and fifth columns by that product for the guns mounted with "no cover, hand-loaded." These quotients perhaps exhibit, as correctly as such an approximate analysis permits, the economic merit of the investments—upon the supposition that the engagement is to last long enough to make the theory of probabilities applicable. Local conditions may materially modify the figures.

ECONOMIC COMPARISON OF DIFFERENT MOUNTINGS.

| MOUNTING. | NUMBER OF 12-INCH 50-TON GUNS IN POSITION FOR $1 000 000. | | | | |
|---|---|---|---|---|---|
| | At maximum judicious cost. | At actual cost. | Shots per hour. | Relative life. | Comparative merit. |
| No cover, hand-loaded...... | .... | 14.0 | 84 | 1.0 | 1.0 |
| Simple barbette............ | 7.7 | 9.0 | 108 | 1.6 | 2.1 |
| King disappearing....... ... | 4.9 | 8.7 | 104 | 2.6 | 3.2 |
| Duane lift................ | 3.4 | 5.9 | 71 | 4.0 | 3.4 |
| Armored casemate......... | 2.2 | 3.4 | 41 | 6.2 | 3.0 |
| Revolving turret........... | 1.0 | 1.0 | 12 | 15.6 | 2.2 |

From this point of view it would appear that the Duane lift and the King disappearing carriage offer the largest return for funds invested in mounting 50-ton guns. King's old-model carriage, mounting a 25-ton 15-inch Rodman gun, was thoroughly tested, and was successful; and there is no doubt that his improved pattern, designed for larger guns, should be experimented with at once.

This comparison as applied to the revolving turret requires qualification. For sea-coast use they can be and usually are made to contain two guns, because this involves less cost per gun than when only one is thus mounted. Moreover, sea-coast turrets are not favored for guns of so small weight as 50 tons. The table, therefore, must not be taken to imply more than it actually expresses. Upon the basis of the above computation, a much more favorable result than appears above would be shown for mounting two 110-ton guns in a single turret.

It will be noted that the moral effect of the protection, real or fancied, afforded by cover in front is left to be taken into account by coefficients to the sixth column of the table, based on individual judgment. It is safe to assume that guns mounted in the open would be deserted under the fire of a modern fleet long before they could be dismounted. Men behind a parapet which conceals the enemy feel comparatively safe; and, by the doctrine of chances, considerable time will elapse before a shot striking where the cover is weak disabuses them of the belief in its efficiency. At the siege of Petersburg the two lines were within murderous musketry range of each other, and rope mantelets to cover the gun-embrasures were a necessity. The first pattern was bullet-proof, but too heavy for convenience, weighing over 500 pounds. Subsequently a lighter pattern which would not certainly stop bullets was used. It

served all purposes. The enemy rarely fired at them, believing that the shots would be thrown away; and our men were as happy behind them as they had been when perfectly protected. War, like all things human, has its successful shams, and cover more apparent than real is often valuable.

# THIRD LECTURE.

## SELECTING THE SITE—HORIZONTAL FIRE.

Sites to prevent bombardment or to cover anchorages—Sites to prevent a forced passage; height and character of the position; development of front; submarine mine requirements—Horizontal fire; range and position-finders; revolving turrets; armored casemates; lifts; disappearing-gun batteries; non-disappearing-gun batteries; flanking guns for mined zones; magazines.

WITH American engineers the objects sought in preparing works of coast defence are: (1) to forbid distant bombardment; (2) to control important anchorages; and (3), by far the most common and the most urgent, to close important channels. Descents in force are little to be feared, and of outlying coaling stations we have none.

The elements of a first-class system for Coast Defence, as already stated, are: (1) high-power guns and mortars for keeping the armored ships of the enemy at a distance; (2) land fortifications to hold the position; (3) obstructions in the channels of approach; (4) flanking guns, movable torpedoes, and the electric light to cover the obstructions; (5) vidette and torpedo boats to watch the enemy and make offensive returns. These elements are of primary importance, and they are the only elements which can be so regarded; their relative importance at different sites will vary, but, according to modern engineering principles, no site is thoroughly defended unless all of them are represented.

These elements hardly admit of intercomparison as to relative importance. Each must be sufficiently elaborate to fulfil its special function at the locality.

Thus, obstructions cannot replace high-power guns; neither can high-power guns replace flanking guns; nor can any or all of them replace fortifications, or vidette and torpedo boats, which are essential to guard against surprise and to make the offensive returns so necessary to any defence in war. When these five elements are judiciously combined and sufficiently developed, they may be trusted to do their work without further assistance, provided the site is favorable.

Considerable latitude is allowed in the composition of these elements.

Thus, obstructions may consist of electrical buoyant or ground mines, self-acting mines not under control, floating barricades, sunken hulks and piling, or sometimes even imaginary obstacles believed to be real by the enemy.

The high-power guns required are not the same at different localities; as a general rule their power need not much exceed what the draught of water permits to be brought against them, and they may be mounted, according to circumstances, in armored turrets, in armored casemates, on lifts, on disappearing carriages, or sometimes even in open barbette. Mortars in pits will be largely used.

A good flanking fire may often be had from 8-inch or 10-inch smooth-bore guns firing canister, grape, shrapnel, and shells; but machine guns, and even low-power rifled cannon, may play an important part. Movable torpedoes under control from the shore and the electric light also fall under this class.

Our cavalry of the sea will certainly comprise fast torpedo-boats, and not impossibly submarine boats of the Nordenfelt class; while it goes without saying that such ships of war as can be spared from their more important and more legitimate field of duty will add powerfully to the defence.

Evidently a modern fortified position on the coast is like an organ with many pipes and stops; and to produce harmony, care and good judgment in the setting-up and skill on the part of the player are required. We have now to deal with the setting-up.

Having, by applying the principles enunciated in former lectures, formed definite ideas as to the strategic importance of the works and as to the scale upon which they are to be constructed, the first duty of the Engineer is to select the site. This requires a thorough understanding of the five elements in their various forms, and a practical knowledge of their several requirements for efficient service.

In actual practice nature often leaves but little choice in fixing upon the best site; but in a theoretical consideration of the subject it is well to decide what is desirable in this connection. The object is to prepare a field of battle in advance where our guns shall overpower anything the enemy can bring against us; where they shall be placed in position in a manner to combine maximum offensive power with minimum vulnerability; where the channel shall be unfavorable for manœuvres and easy to obstruct; and, in a word, where we shall have every advantage.

### SITES TO PREVENT BOMBARDMENT OR COVER ANCHORAGES.

Unquestionably a primary object in view is to secure the place to be defended against distant bombardment, which, so long as the enemy is kept outside the barrier erected in his path, is his natural mode of attack. At some places situated on great rivers or in deep indentations of the coast—as, for example, at New Orleans, at Philadelphia, at Baltimore, and at Washington—this problem is easy; at others—as, for example, at the Naval Depot formerly projected at the Dry Tortugas, which is situated

upon a small island surrounded by a narrow cordon of sand-keys and coral-reefs, outside of which the enemy could deploy and maintain through an arc of 360° a concentrated fire at easy ranges—the problem to-day admits of no solution, and the project has been abandoned. Between these extreme conditions we have many harbors which must be defended, and the question arises in each case what kind and amount of fire must be provided, and what other means may be employed to convince the naval commander that he has more to lose than to gain from the contingent advantage of shelling the port at long range. This problem involves: (1) the effective range of modern high-power guns mounted on shipboard; (2) the amount of damage they will probably inflict upon the port in question; and (3) what kind and amount of land-fire and what other expedients will best produce the desired conviction that bombardment is inexpedient. Each of these questions admits of differences of opinion, and I can only give my own.

I. As to the extreme ranges to be expected from naval guns, I assume, with Lieut. Very and others, that from 13° to 15° is the maximum practicable elevation for guns on shipboard. At 14° Krupp's 30.5-centimetre gun, 35 calibres long, has thrown its projectile about 6.5 miles. Without entering into a discussion of the subject, which in this company would be travelling over familiar ground, I will state that as an engineer officer I have little expectation that bombardment from shipboard will ever be seriously attempted at ranges exceeding six or possibly seven miles; and bearing in mind the tremendous shock upon the deck which cannot be avoided in such practice, the immense number of shots required for effective work where the results cannot be accurately noted, and the short life even of the best modern high-power guns, I do not believe that we have much

to fear at so long ranges, or, indeed, at ranges considerably less than those named. That these views are entertained abroad is sufficiently shown by the discussion of the problem for Spezzia, mentioned in a former lecture, where the engineers considered 4.6 miles as sufficient to secure even their chief naval establishment against unendurable annoyance.

Even in conservative England the dangers of bombardment at panic ranges are discounted. Colonel Schaw, R.E., the well-known Deputy Director of Works for Fortification, said, in a lecture delivered before the Royal United Service Institution less than a year ago: "Bombardments are now possible at ranges of 8 000 to 10 000 yards distance, which would have seemed fabulous in former days; and although the actual destruction produced by a bombardment may be less than would be at first sight thought probable, yet, if ammunition be plentiful, it is undoubtedly very serious, and may be disastrous if magazines be exploded or important storehouses set on fire.

"Dockyards are perhaps less inflammable now than they were in former days, as iron enters so largely into the construction of our ships; yet a great quantity of wood and other materials that can be set on fire must be found in every dockyard, and, in any case, the bursting of large shells containing many pounds of powder, or perhaps dynamite, will work great havoc."

It will be noticed that he limits the dangerous range to from 8 000 to 10 000 yards—*i.e.*, from 4.5 to 6.0 miles.

In the discussion which followed the reading of the paper, Captain Henderson, Royal Navy, made use of the following language: "I doubt the efficiency of bombardment at long ranges by ships under way (for ships cannot anchor for this purpose if exposed to gun-fire or Whitehead attack), against un-

seen objects, without any knowledge of the damage done; for the short life of breech-loading heavy rifled guns necessitates every shot being carefully husbanded." No speaker criticised this conclusion or suggested a longer range as dangerous. Like continuous picket-firing on the lines of an army, the results will not compensate the outlay, for reasons independent of the ballistic power of the guns.

II. As to the damage which can be inflicted at these extreme ranges, experience at Charleston, Vicksburg, Petersburg, and even Paris, has shown that many siege projectiles may fall within the limits of a city without compelling a surrender. The larger sizes of naval shells will produce more destructive results, and, among buildings like those in the lower part of New York, they would probably prove unendurable; but in a sparsely settled city like Galveston I should not apprehend a decisive result.

III. As to what expedients are best to deter vessels from indulging in distant bombardment, or to cover important anchorages, I attach great importance to a well-directed fire from many heavy mortars, in pits quite out of sight, having a range of 5 miles, and so mounted as to bring their fire perfectly under the control of one officer. By mounting them compactly on centre-pintle carriages, with traverse-circles graduated to 360° from a common origin of azimuths, this is easily accomplished, as will appear in the next lecture. Supplemented by outlying groups of detached mines to be fired by judgment, and by a swarm of fast torpedo-boats ready to rush upon the enemy when enveloped by the smoke of his own guns, these mortars, I think, would soon bring about the desired frame of mind.

In fine, with proper arrangements, I believe little is to be feared from distant bombardment when our defensive works are placed at six miles outside the

object to be defended, be it a densely populated city, a depot, a navy-yard, or a port crowded with vessels of commerce. Still, if ten miles be practicable at reasonable expense, no engineer to-day would probably choose a less distance for works to prevent distant bombardment.

### SITES TO PREVENT A FORCED PASSAGE.

In selecting a line for blocking the entrance, certain local conditions are desirable—such are a single channel, a favorable height and character of banks, a well-developed front for ourselves, a contracted front of attack, and a channel easy to obstruct; the latter calling for moderate depth, small tidal range, gentle currents, water sufficiently turbid to conceal mines, and a muddy bottom to bury the electric cables. Each will be considered in turn.

**Height and Character of the Position.**—A low site near the sea-level possesses a single advantage over one moderately high—it favors ricochet fire. But in the days of smooth-bore guns and wooden ships this was the most effective kind of fire known, because a small error in elevation or a variation in strength of powder did not prevent destructive hits. For this reason water-batteries were often placed at the water's edge, even when such locations involved extra expense in foundations. Fort Wadsworth, in New York Harbor, is an example in point.

With rifled guns this advantage has lost much of its value, even against unarmored ships, because after striking the water the projectile often diverges widely from the plane of fire. Still, as many old smooth-bore guns will continue to be used for the flanking of submarine mines when attacked by boats, ricochet fire is not entirely obsolete even to-day. Against armored ships it could no longer be used, because after even one grazing impact on water so much of

the velocity is lost as to destroy the effective energy of the largest projectile.

On the other hand, a low site for land guns entails many disadvantages. (1) It affords no direct fire upon the deck of a ship, which, being her most vulnerable point, should always be attacked. (2) It enables ships to dispense with high angles of fire, for which the mode of mounting their guns in a measure disqualifies them. (3) It places the hostile guns on shipboard on an equality with land guns as to energy of impact—an advantage which nature denies them in attacking a high battery. For example, a 16-inch rifle, firing projectiles weighing one ton from a bluff 200 feet high, will have its effective energy of impact increased 200 foot-tons by gravity—a matter worth considering when striking a plunging blow upon a 3-inch steel deck. A similar gun returning this fire from shipboard will lose an equal amount of energy in the projectile, which must be raised against gravity to the top of the bluff; the ship will therefore be handicapped to the extent of 400 foot-tons for every shot in a duel fought under such conditions. (4) The depression of the axis of the land gun fired from a high site tends to make the trajectory more nearly normal to the deck, while the corresponding elevation of the axis of the gun on shipboard tends, at short ranges, to make its trajectory still more oblique to the parapet, and especially more oblique to inclined armor. (5) A high site compels the ship to keep herself at a certain distance in order to bring the guns to bear, and thus interferes with the precision of fire needful to dismount land guns attacked from a moving gun platform like the deck of a ship. Even at Fort Mex, a low work at Alexandria, out of 920 shots fired at 14 guns practically *en barbette* by five armored ships at ranges from 1 000 to 3 800 yards, two land guns were perhaps grazed but none were dis-

abled by direct hits; and only direct hits can place a gun properly mounted on a bluff *hors de combat.*

These considerations make it evident that where nature has provided moderately high sites (say from 100 to 200 feet) they should be occupied by the fortifications of to-day. The question was not so simple in 1864, when it was brought seriously to the attention of a special Board of Engineers convened, in view of the then recent changes in guns and of the introduction of armor, to report what should be done in respect to fortifications under actual construction. We were not prepared at that date to entirely sacrifice the advantages of ricochet fire; but no data existed to decide definitely how much would be lost by placing the guns considerably above the water.

The problem, about this time, was discussed analytically in a paper written by Prof. C. A. Schott, of the Coast Survey, at the instance of General A. P. Howe, Inspector of Artillery, U. S. A., and his results were submitted by the latter in a report to the Chief of Engineers. Mr. Schott based his computations upon the assumption that the angle of rebound from the water was equal to the angle of incidence—an assumption which I could not accept. After the war was over, in the summer of 1865, accident placed my brigade of volunteer artillery troops for a short time in the Defenses of Washington; and I took advantage of the opportunity to investigate the problem by firing shots with 15-inch guns at the heights of 36 feet and 103 feet above the waters of the Potomac. These data I subsequently subjected to mathematical analysis; and General Haskin, of the Artillery, kindly checked the results by firing, in 1867, at Fort Schuyler, New York Harbor, with an 8-inch Rodman gun and a 24-pounder, at heights above the water of 38 feet and 15 feet respectively. This investigation led to definite formulæ and con-

clusions, which are reported in full in Professional Papers No. 14 of the Corps of Engineers.

Briefly, the results may be stated as follows: Rebounds cease when the angle of incidence increases to about 8 degrees, whether fired from heights of 15 feet or 103 feet. The angles of rebound at the first and subsequent impacts are always greater than those of incidence; and they follow a law which was experimentally deduced. The loss in the ricochet trajectories of the 15-inch gun, caused by increasing its height above the water, proved to be not so great as had been imagined. For example, with spherical shells, weighing 344 lbs. and having an initial velocity of 1 166 feet per second (assuming that such projectiles are dangerous to unarmored vessels when moving with a velocity not less than 300 feet per second at a height above the water not greater than 25 feet), the lengths of dangerous ricochet trajectories are as follows:

| HEIGHT OF GUN. FEET. | DANGEROUS TRAJECTORY. YARDS. | TOTAL TRAJECTORY. YARDS. |
|---|---|---|
| 10 | 3428 | 4152 |
| 36 | 3122 | 4457 |
| 60 | 1924 | 3758 |
| 104 | 821 | 2706 |
| 150 | 481 | 1934 |
| 200 | 291 | 1508 |
| 250 | 63 | 1117 |

With residual velocities not less than 400 feet, and heights of projectiles above the water surface not greater than 20 feet, these figures become:

| HEIGHT OF GUN. FEET. | DANGEROUS TRAJECTORY. YARDS. | TOTAL TRAJECTORY. YARDS. |
|---|---|---|
| 10 | 3007 | 4152 |
| 36 | 2311 | 4457 |
| 60 | 1174 | 3758 |
| 104 | 433 | 2706 |
| 150 | 204 | 1934 |
| 200 | 57 | 1508 |
| 250 | 50 | 1117 |

With the smooth-bore ordnance in service when our provisional earthen-battery system was planned, it is plain that a trajectory useful for ricochet fire for fully one-quarter of a mile was secured, even with our guns raised 100 feet above the water; and whenever this height was available it was selected in locating the works. We would do the same, for stronger reasons, with the ordnance of to-day.

There are, of course, limits which should not be exceeded in raising guns above the water. With a depression of 7°, which is about the maximum provided for by modern carriages and mountings, the dead angle in front of a gun 200 feet above the water would cover 543 yards; at 400 feet above the water this space would be 1 086 yards wide. If a deep channel past the position lay within this space, it would evidently be necessary to place at least part of the armament at a lower level.

The height of the site exercises a controlling influence upon the mode of mounting and covering the guns. The object sought is to combine the widest possible range and traverse with the least risk of being silenced by the enemy's fire. If the site be low and the adjacent water deep, the position is very unfavorable and an open barbette mounting is inadmissible; for the ships would approach within less than 1 000 yards, and with shrapnel and machine-gun fire would render it impossible to serve the guns. Turrets for 100-ton guns and casemates or lifts for 50-ton guns are imperative for such sites. With heights 300 or 400 feet above tide the conditions are far more favorable, and open barbette batteries may be constructed with reasonable chances of effective service. For intermediate heights, especially if shoal water or mine fields prevent the near approach of the vessels, disappearing guns in barbette batteries may be trusted to do good service. On cliffs 500 feet

high, like some of those which border the Golden Gate, land guns, however mounted, have enormous advantages: the target is enlarged by the area of the deck, the fire is plunging, the enemy at short ranges has difficulty in elevating his guns, and his shots pass over with little fall. On the other hand, provision must be made to cover the dead angle left near the shore.

When a choice is given between a low site near the water and a bluff in rear, the question of relative cost will often decide whether a more powerful gun *en barbette* on the bluff or a less powerful gun in a more expensive form of battery near the water shall be preferred. Equal armor-piercing power at a two-mile range should be secured.

There are, of course, other matters connected with the banks besides height which have influence in selecting the site. Forests are always advantageous, because they favor concealment; and for mortar batteries, from which no sight of the enemy is required, this is so important that, if not *in situ*, trees will often have to be cultivated. The character of the soil and of the foundation; the absence of ledges of rock, which will enhance the cost of construction; and many other matters pertaining to the details of the profession, must have due consideration, although they need not be dwelt upon here.

**Development of Front.**—The batteries of the defence should be widely distributed: (1) to avoid accumulations of smoke, which interfere with the accurate firing demanded of modern guns; this matter is more serious than formerly when far smaller charges were burned, and when shorter ranges and ricochet firing rendered precision in pointing less important; (2) to avoid the concentration of fire which can be brought against a contracted site; shots aimed at one gun, under such circumstances, may take effect

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upon its neighbor, and bursting shells or accidental explosions will cause the maximum of destruction; (3) because a widely-developed land front favors cross-fire, which is exceedingly effective upon some types of modern shipping, such, for example, as that of the *Benbow*, where 110-ton guns are exposed *en barbette.* Fighting "head on" may be thus rendered impracticable, except at too long ranges to be effective.

On the other hand, in selecting the position the enemy should be forced, when possible, to make use of a contracted front; he will thus not only be subjected to the inconveniences named above, but also may be prevented from developing his full power, and will certainly be thrown into confusion should some of his vessels become unmanageable during the engagement.

The map and the ground should both be studied with a view to selecting a site combining the two advantages of a wide development of fire for ourselves and a contracted front for the enemy. For example, the choice may lie between occupying projecting head lands where our guns must be massed on the seashore, and where the enemy may develop his attack from a semi-circle, with all his vessels advantageously placed; or choosing an interior position where our guns may be scattered widely while his front is restricted to a narrow channel. In such cases the latter site will always be selected by an engineer. A long, narrow gorge opening in rear into a small bay, or a sharp bend in the channel, will usually be occupied by the defence rather than a position still farther to the rear which enables the enemy to deploy in the bay or to escape from a dangerous triangle. The approaches to Melbourne present a good example of the first class of positions; and the East River entrance to New York harbor, one of the second. The posi-

tion at the Narrows is a familiar illustration where the natural conditions offer great advantages to the defence.

**Submarine Mine Requirements.**—Shallow water, gentle currents, and small tidal range should have great weight in choosing a site for blocking the channel, whether by the older plans or by submarine mines, which to-day afford the best and simplest mode of so doing available to the engineer. Under certain circumstances these conditions may of themselves modify the selection of the position; for where the mines are, there must also be an array of land guns to cover them. San Francisco is a case in point.

This matter will be rendered more clear by considering briefly a few details. The smaller a buoyant torpedo is made, the more easy it is handled and the more likely will it be to remain effective for a long period. Even in still water enough buoyancy must be given to support the torpedo-case, the charge, the mooring ropes, and the electric cable; in a strong current its depressing effect must also be taken into account or the torpedo will sink too deep to be struck by a passing vessel. With our spherical pattern the buoyancy varies with the cube of the radius, while the great circle cross-section varies with the square of the radius. But the horizontal thrust due to the current is directly proportional to the great circle cross-section, and may be estimated in pounds per square foot, when applied to the spherical surface of our adopted pattern, by taking one-half of the square of the velocity in feet. That is, a spherical torpedo 32 inches in diameter, having 6 square feet of cross-section, when moored in a current of 7 feet per second, will experience a horizontal thrust of about $6 \times \frac{1}{2} \times 7^2 = 147$ pounds. But this thrust is also applied to the mooring and electric cable, which in water 50 feet deep about doubles its intensity—giving

in this case a horizontal thrust of about 300 pounds to be overcome by buoyancy additional to what is required in still water. But to obtain increased buoyancy sufficient to prevent the torpedo from being carried below the draught of the vessel, its size and hence the above figures must also be increased—and increased very considerably—since the gain varies only as the cube of the radius, while the increased thrust varies as the square of that quantity.

These figures give an idea of the great difficulties which beset the submarine miner when he has to contend with a strong current. Great depths are hardly less objectionable; for not only is the increased weight of mooring and cable (about one pound per running foot) to be supported, but also the admissible angular deflection to prevent too great depression of the torpedo is rapidly reduced, and the absolute buoyancy needful from this cause is correspondingly increased. Practically a depth of 100 feet with a current of 7 feet per second fixes the admissible limit within which submarine mining is effective in our harbors; and defensive positions must be chosen accordingly.

Excessive tidal ranges, such as prevail in the English Channel (20 feet and upward), can only be overcome by a double system of mines—one for low water, and another in rear of the first for high water. Very fortunately we are not afflicted with such tides on our coast, where 10 feet is about the maximum in any harbor of first-class importance; hence this double system is not necessary in our projects for submarine mines.

After duly considering these matters of distant bombardment, practicable height of batteries, nature of the soil, development of front for himself and contraction of front for the enemy, depth of water, and the tidal range and velocities of currents at the

different stages, the engineer selects his site or sites and proceeds to study the extent to be covered by his submarine mines, the needful armament, and the exact character and location of his works.

### HORIZONTAL FIRE.

An early matter for consideration is: What shall constitute the land armament and how shall it be placed in position? This subject was referred by Congress for report to a special Board, of which the Secretary of War, Judge Endicott, was president—consisting of two officers of the Engineer Corps of the Army, two officers of the Ordnance Department of the Army, two officers of the line of the Navy, and two civilian experts in steel manufacture.

This Board, in January, 1886, endorsing the views of the Board of Engineers and of the last Armament Board (July, 1884), recommended, exclusive of old guns now on hand, the adoption of modern high-power guns fabricated entirely of steel. For the land defence of the twenty-seven most important seaports of the United States the following calibres and numbers were specified, viz.: 44 16-inch guns, 6 14-inch guns, 203 12-inch guns, 222 10-inch guns, 102 8-inch guns, 4 6-inch guns, 700 12-inch rifled mortars, and 24 10-inch rifled mortars; also 5 floating batteries, 150 torpedo-boats, 12 special torpedo-gunboats for the Lakes, and 6 161 submarine mines.

Summing up the total new armament recommended for the twenty-seven ports, we find 581 guns of all calibres and 724 mortars. The 16-inch 110-ton guns are recommended to be mounted in revolving turrets; the smaller calibres in armored casements, on lifts, or on disappearing or non-disappearing carriages, according to the peculiarities of the sites. The mortars are to be served in groups from pits entirely concealed, when practicable, from the enemy's view.

I shall confine myself to-day to discussing the different modes of providing for the horizontal fire.

The power and character of the proposed guns, and reasons for their selection, are so familiar to all present that time would be wasted in discussing them; but a few words upon recent improvements in land-pointing will not be out of place.

**Range and Position Finders.**—The change from many small guns to few large guns in coast defence has vastly increased the importance of making every shot tell. For this reason the subject of range-finding has received much study of late years, and many devices have been presented for trial. For sea-coast works where an altitude of not less than fifty or sixty feet can be obtained, the principle which seems to lend itself best to the requirements of the problem is that of "depression angles": *i.e.*, the angle is measured between the horizontal and a line drawn to the water-surface at the object whose distance is desired; this being the parallax of the known height of the instrument above the water as seen from that object, the distance may either be determined by calculation or be read from a scale on the instrument. The accuracy attained by some of these new devices is wonderful. One of the best, known as the Watkin Depression Range-Finder, is claimed to give an error of only about half a dozen yards at a range of 2 000 yards.

Where the site is low the use of horizontal angles becomes necessary; and two observers at a considerable distance from each other, or a very delicate and costly instrument with a short base, may be employed, according to circumstances.

But there is another difficulty inherent to modern practice—viz., the volumes of smoke caused by burning so large charges, which makes it very desirable to know more than the simple distance to the object.

This necessity, and the advantages which grow out of having one general system of range-finding instead of isolated measurements, have led to the introduction of "position-finders." These instruments define the ship's exact position at any instant of time; and by having the map divided into squares some forty or fifty yards on the edge, and supplying lists at the batteries giving the corresponding elevation and azimuths, the guns, even when completely shrouded in smoke, may be served with precision by orders telegraphed from a distant station where the fleet is in view.

The first system of position finding was devised by Mr. Madsen, and was introduced at Copenhagen in the war of 1864 by Colonel Ernst, of the Danish Engineers. It was a complex system of triangulation by theodolites, under electrical control from a central station.

This plan was succeeded by the well-known Distance-Measurer of Siemens, by which, through the aid of electricity, a light arm is caused to move over a chart at a distant station, always retaining its parallelism to the axis of the governing telescope. The complexity of this system and the practical difficulties attending it are the chief objections, and they apply to the similar plan of Major Watkin, R.A., submitted in 1867. In all of these three methods the system of corresponding squares on the chart and on the water forms the basis of the operation, and it is evident that any well-considered plan of triangulation can be adapted to the same principle. Major Watkin's electrical position-finder was tried at Picklecombe Battery in actual practice at a moving target, and with decided success.

When a height of not less than 60 or 80 feet above the water can be had, Major Watkin has modified his range-finder to give azimuths as well as distances;

and thus, at a single station which may be far removed from smoke or hostile artillery practice, the pointing of every gun in every battery may be regulated by ordinary telegraphy—the actual firing may be done at the battery or by electricity from the observing station. This system is now adopted in the English land service, and no doubt the same, or something similar, will hereafter be used in all sea-coast fortresses. Suitable stations are easily prepared at most of our ports.

Speaking of this system before the Royal United Service Institution within less than a year, Colonel Schaw, R.E., Deputy Director of Works for Fortification, said: "This sounds too complicated and scientific to be practicable; but seeing is believing. The system is no longer a project, but an accomplished fact, which I have witnessed in successful operation, and which I hope may soon be applied to every important battery we possess. . . . The percentage of hits will be probably increased tenfold."

**Mounting Land Guns.**—Reverting to how land guns should be mounted, it is to be noted that so soon as a resort is had to horizontal fire we are compelled to face the problem of how best to encounter the flying asteroids now to be expected in naval warfare. Five principal plans are in use to-day—turrets of various types; armored casemates; lifts by which the gun with its platform complete is raised to fire over the parapet, and then lowered at once for cover while reloading; disappearing carriages operated in a similar manner from a fixed platform, but utilizing the force of recoil to raise the gun; and the open barbette mounting.

One remark is to be made emphatically at the outset. No matter what kind of protection is chosen, some of the defenders will be hurt. It appears to be expected in some quarters that the same men who are

to be disciplined to endure the loss of one-third of their numbers in serving a light battery in action, are to be guaranteed entire safety as to life and limb in serving the armament of a sea-coast fortress. This is asking too much of the engineer, and is raising a false standard by which to judge of his work. Where blows are to be received measured by the impact of the New York obelisk dropped from the top of Trinity Church steeple, it is idle to look for absolute security. Let us hope, before the time comes, to have in readiness works offering reasonable chances of safety; but if not, our soldiers may be trusted not to disgrace the flag. If there were no risks to be encountered, the service would cease to be war and soldiers would become mere laborers.

**Revolving Turrets.**—The details of revolving turrets, with their machinery and gun-carriages, are so similar to like arrangements on shipboard that time would be wasted in discussing them.

Land turrets are surrounded by a massive masonry glacis, below which, and properly covered, are the magazines, the shell-rooms, the engine and boiler rooms, the quarters for the garrison in war, and such store-rooms for coal, etc., as are necessary for the service of the guns. All these appurtenances may be thoroughly protected; and in this respect land turrets have decidedly the advantage over those on shipboard, which must always be liable to become unserviceable from any serious injury to the ship itself, whether caused by a gun, by a mortar, by a submarine mine, or even by a rock or shoal.

On land serious difficulty is experienced in preventing fragments, dislodged from the masonry glacis in the near vicinity of the base of the turret, from becoming wedged in a manner to prevent its rotation. This is attempted to be obviated in the Dover turret by embedding in the masonry two ver-

tical wrought-iron plates parallel to each other, on circumferences concentric with the turret. Gruson provides a massive glacis ring of chilled cast-iron, buried in part under the masonry, but curving to the rear to form half of a roof of a *chemin des rondes* passing around the concealed truss which supports the weight of the turret. The bottom surface of the turret itself forms the other half of this roof. The junction between the two, near the crown of the arch, is well protected against impact by the curved form of both parts; and the space between the plates is too small to admit fragments of stone large enough to stop rotation against the power of the engines. This arrangement appears to be excellent.

The tendency at present is to replace the cylindrical form of turret by that of a cupola, with curved surfaces inclined to the horizon—the object being to break and deflect the projectiles by opposing only an oblique surface. This form, admirable everywhere else, entails serious consequences round the embrasures by the excessive cutting away of the metal necessary to accommodate the gun. Protection immediately over the chase is certainly apparent rather than real; and, worse still, the effect of a very powerful blow upon the iron mass between the two embrasures, where it has little or no lateral support, becomes, to say the least, doubtful; experiment heretofore has thrown no light on this difficulty. In these two particulars the new form is far inferior to the old; it is the price paid for the unquestioned advantages resulting from obliquity of impact. Unfortunately the weak place falls immediately in front of the guns, where it can be least favored by rapid and skilful manipulation of the revolving mechanism. A shattering blow here could not but be fatal to both guns.

Another form of two-gun turret, known in Eng-

land as the Collingwood mounting, is attracting attention for land uses. The embrasures of the ordinary turret are omitted, and the gun, mounted upon a hydro-pneumatic carriage, is fired in barbette. The breech is lowered for loading, leaving the muzzle always exposed. The interior space is covered with a steel deck, with openings to permit raising and lowering the guns. In this arrangement rotation is given by a turn-table, the heavy armored walls remaining fixed in position; they are made of inclined iron covered entirely with masonry in the form of a glacis.

The question of the kind of armor is still an open one for land turrets. They have been actually constructed of wrought iron and of chilled cast iron, the latter being now generally preferred on the Continent of Europe; they have never been made either of compound plates or of steel. The chief reason for giving preference in naval constructions to compound or steel armor—less weight for equal protection—loses much of its force when applied to a land turret. The subject will be considered more fully in a subsequent lecture, and I will now simply express my opinion that judgment in this country should be held in suspense for the present.

There are serious objections to the use of any form of turret in coast-defence. They are enormously expensive; they somewhat restrict the elevation of the guns; and, like all complex machines, they are liable to become unserviceable in action by a single lucky shot which may jam a gun in its embrasure, or by any chance accident to the mechanism which may render it impossible to revolve the turret or to serve the ammunition. On the other hand, they afford more perfect cover to the guns, the personnel, and the machinery for loading and pointing than any other known mode of protection; they simplify

the carriage (a matter of no small importance with guns of this weight), since no azimuth motion aside from that of the turret itself is required; they afford an all-round fire; in the event of an overpowering concentration upon a single turret they permit all vulnerable parts to be withdrawn temporarily from action by revolving the embrasures to the rear; and, lastly, where nature has too much restricted the area of the site, they compress into the smallest space the maximum possible offensive power.

The balance between these merits and demerits evidently becomes more favorable as the weight and power of the guns increase. In our projects turrets are proposed only for the 16-inch 110-ton gun, or for larger calibres if such should ever become necessary, and for low sites where a wide field of fire is demanded. Under such conditions it must be remembered that their cost, although great, is less than half of the sums which have been expended for similar guns to be brought against us on armored ships, and less even than that of single buildings in our great cities, which without their protection may be reduced to heaps of ruins. Twenty-two of them were recommended by the Endicott Board.

**Armored Casemates.**—This mode of covering guns so much restricts their field of fire that it has only a limited application. About 15 degrees in elevation and 60 degrees in traverse (30 on each side of the perpendicular) are all which can be given. If a larger traverse is demanded, the best way is to increase the number of guns and dispose them on a polygon giving the needful dispersion. A hexagon is usually the best form to select, because all the guns on two adjacent fronts can be brought to bear upon a vessel lying on the line bisecting the angle included between these fronts. If a polygon of a greater number of sides be selected, there will be a

wasteful overlap of fire; if of a less number of sides, there will be a dead angle which will be taken advantage of by a skilful Naval Commander—as was done in selecting the anchorage for the iron-clad vessels at the bombardment of Fort Fisher.

This kind of protection permits no temporary withdrawal of the armament from action, either for repairs or to escape a concentration of hostile fire; and this objection is aggravated by the fact that perhaps no form of battery is so difficult to design to meet the conflicting requirements of the problem.

The old composite form of iron shields and masonry merlons has long been out of date. An all-iron scarp is now universally adopted, with a single tier of guns, and with the magazines, etc., in casemates below them where perfect protection can be given. For low sites this form of battery affords better cover than any other except turrets. The cost is materially reduced by combining several guns in the same battery; it is usual to consider from three to five as the minimum number. They are necessarily crowded in a small space, and the annoyance of smoke in preventing accurate aim may well be feared. The question of the kind of armor to be used is the same as for turrets. It is still an open one in our service.

Until the dimensions of gun and carriage are definitely determined it is impossible to form precise rules for the interior space needful in a casemate. A sufficiently close approximation for all general purposes may be had, however, from the English rule, which is based on large experience with modern guns and iron structures. It is in substance the following: Strike an arc from the pintle as a centre, with a radius of 24.5 feet; the space included between the extreme lines of fire, with four feet beyond them, will afford enough floor space for any gun up to the

12.5-inch of 38 tons. The 12-inch 43-ton B. L. gun requires a radius of 26.5 feet, and one of 28.5 feet is favored. A clear height of 9 feet is sufficient.

Casemate magazines are usually now placed in a second tier under the guns, fitted with suitable lifts for supplying ammunition. These lifts should be placed in the rear piers, enlarged slightly for the purpose, where danger of accidental explosions communicating to the magazines below is at a minimum, and where the space required for serving the guns is not encroached upon.

Reducing the size of the gun makes comparatively little difference in the cost of the casemate, which is chiefly dependent upon the size of the armament to be brought against it. Hence only one type, suited to the 12-inch 50-ton gun, is proposed for our service, and it is restricted to low sites. Casemates for eighty of these guns were recommended by the Endicott Board.

**Lifts.**—This class of mounting dispenses with the use of armor entirely, or at any rate restricts its use to a light bomb proof roofing which may be sometimes used to stop fragments of shells and shrapnel-balls. The gun and its platform are placed behind a suitable parapet, and by hydraulic power, with or without the aid of counterpoises, are raised and lowered at pleasure. When in the firing position the gun has all the capacity as to elevation and traverse afforded by the best barbette carriage, even, if necessary, being given a traverse of 360 degrees; but no sooner is its work done than it sinks out of sight and is loaded, so far as horizontal fire is concerned, in perfect safety.

Guns have been actually mounted upon this principle for several years at Cronstadt and at Alexandria; and the *Téméraire* and other armored vessels carry guns disposed in a similar manner. General Duane, when president of the Board of Engineers,

gave careful study to the subject, and devised two types, one with and the other without counterpoises, which met with such favor before the Endicott Board that the construction of 54 of them was recommended for the defence of the Coast.

Lifts are usually restricted to the mounting of the 12-inch 50-ton gun, and are preferred for medium heights where a wide traverse is required. They would serve an excellent purpose as the chief defence of secondary ports where the depth of water in the channel will not permit the entrance of vessels carrying a more powerful armament than the 12-inch gun. The cost is estimated at $100 000 per gun, and it is greatly to be desired that the construction of one of them should at once be undertaken, to enable the minor details to be perfected by trial.

This mode of mounting possesses so many and such incontestable merits that a few details may prove interesting. The two types devised by General Duane differ only in the mode of applying power to the raising and lowering of the platform. They have in common a substantial parapet to resist the fire of the heaviest gun which can be brought against them Usually the front of this parapet would be of earth, but near the guns it must be of massive masonry, presenting only a horizontal surface to the fire of the enemy. The crest is broken by semi-circular recesses, 50 feet in diameter, to receive the guns, which are placed at a minimum distance of 74 feet apart. The centres of these semi-circles are five feet in front of the crest, giving a horizontal angle of fire of 180 degrees. The arrangements behind the parapet dispense with the use of traverses—a very great advantage, as their absence destroys the usual clue to the position of the guns. The latter are mounted on any form of low centre-pintle barbette carriage, which is supported by a circular platform 26 feet in

diameter. This platform, when in the firing position, forms part of the masonry floor of the recess, the reference being six feet below the crest. This floor extends unbroken to the rear for 50 feet from the centre of motion of the gun. Covered by it are two tiers of casemates for magazines, shell-rooms, etc.; and in front of them on the side of the gun is a long gallery, parallel to the crest, for communications, hydraulic machinery, etc. The circular platform rests on a trussed staging, and can be lowered 14 feet to the loading position. The muzzle of the gun in the firing position extends well over the crest. After the recoil, if not already there, it is traversed to the front, where, within an angle of 60 degrees, the flooring is cut away to form a recess to receive the muzzle in lowering. Loading is done from a fixed position, the usual shot-lift supplying the ammunition in front of an hydraulic rammer to force it home in the gun.

As already stated, the foregoing arrangements are common to both of General Duane's devices. In one of them the gun platform is lowered and raised by means of six counterweights and an hydraulic accumulator which communicates by pipe with the gun-lift. The counterweights are connected by wire ropes, running over drums, to the foot girders of the platform staging. The total weight of gun, platform, and staging is greater than the combined weight of the counterweights, causing the gun to descend when connection with the accumulator is turned off and the waste-cock of the gun-lift is opened. The pressure of the accumulator, when transmitted to the ram of the gun-lift, is greater than the preponderance of the gun and staging, and will raise them to the firing position.

The other device is operated without counterweights by a more powerful hydraulic ram, in the manner usual to such mechanism. Experiment is needed to determine which is the better arrangement.

**Disappearing Gun-Batteries.**—The invention of a carriage which, without change of level in the platform, shall remove the gun from sight when fired, and by this motion shall store up the power needful to raise it again when wanted, has long engaged the attention of engineers as well as of artillerists.

The advantages of such a mode of mounting are great. (1) The gun is exposed to injury only during the firing. If overpowered it may remain under cover, always ready to resume action when the enemy is tired of throwing away his ammunition. In a word, such a battery can never be "silenced" until the guns are hit. (2) The greater part of the personnel is permanently under cover, and the casualties will consequently be few. (3) When guns are mounted in this manner no satisfactory reconnoissance can be made by the enemy. I attach no little importance to this matter, having myself experienced a like difficulty in land operations. The Confederates sometimes withdrew their field-guns from the barbettes, so that the most careful scrutiny gave no information as to the artillery fire to which a charge would be subjected. As soon as the assault was delivered, flanking guns would appear as if by magic, and with results far exceeding what would have been accomplished if their position had been known and our guns had been disposed accordingly.

Many different disappearing carriages have been devised. No less than five distinct systems have been introduced, but most of them are applicable only to guns of small calibre. The Moncrief counterpoise carriage will only carry guns about five tons in weight. King's carriage, which alone has had a practical trial in this country, has proved itself successful with the 15-inch 25-ton smooth-bore gun; and his new adaptation for a 12-inch 50-ton gun ought to be experimentally tested, without delay, in competi-

tion with the Buffington and any other device which promises success. The Moncrief hydro-pneumatic carriage, the Rendel carriage, the Raskasoff carriage, and other types are favorably regarded abroad. Armstrong now furnishes a disappearing carriage for guns 70 tons in weight.

The excessive length of modern high-power guns, and the loading at the breech, have increased the difficulty of properly covering this type of carriage—not only from the greater weights to be handled, but also from the comparatively exposed position of the cannoniers, which is so far removed from the parapet that curved fire becomes annoying.

A special form of battery suited to receive the new King carriage has been devised by the Board of Engineers. The gun may be loaded from the extreme rear; but being exposed in that position to shrapnel fire, and to shot descending at an angle of ten or more degrees, provision has been made for revolving the gun to a position parallel to the crest, and there loading it from a passage in a bomb-proof traverse, which contains, in sub-casemates, the magazines, shell-rooms, etc. The cost of this battery is small, about $15 000, and its efficiency in positions of moderate height will be great. Cover is estimated at the rate of 70 feet of sand, or its equivalent in concrete or stone masonry. The gun is lowered 8 feet. In extending the battery an interval of 124 feet is left between guns. The traverses rise 11 feet above, and the terreplein is 12 feet below the level of the crest. A sunken passage 6 feet below the terreplein affords secure communications and fair cover for men engaged in loading in the open.

**Non-disappearing Gun-Batteries.**—Probably new batteries of this class will be restricted to exceptionally high sites, where they will certainly be troublesome to the enemy. Simplicity and economy

are their chief merits. The only part of our present armament which could with any chance of success reply to the fire of modern guns is thus mounted, and most of the batteries were constructed to admit of the introduction of the old King carriage, if desired.

It is to be noted, however, that although now viewed with suspicion from perhaps exaggerated estimates of the efficiency of shrapnel and of rapid-firing guns on shipboard, there are indications that where vessels can be kept at a distance this mode of mounting may again receive favor. Thus the French have adopted a simple barbette mounting for the heavy armament (four 46-ton guns) of the *Admiral Duperré* and for other ships; and the English have followed their example in the *Impérieuse*, the *Warspite*, and even in the *Benbow*. Nay, more, the heaviest guns now mounted in English land defences (the four 100-ton Armstrong guns at Gibraltar and Malta) are placed in barbette behind a high parapet about 100 feet above the water. They are provided, however, with a complete under-cover system of loading.

The change from muzzle-loading to breech-loading has, upon the whole, done much to increase the efficiency of barbette batteries. Although the cannoniers are stationed further from the parapet, and are therefore more exposed to curved fire, the gun itself is a great protection to them, especially at high elevations; and cover against small missiles is easily given by steel hoods enveloping the breech.

**Flanking Guns for Mined Zones.**—None of the modern high-power guns are well adapted for use in flanking, being too heavy and too few in number to be effective in such work. Machine and rapid-firing guns will doubtless play an important part in such operations, especially for new works where no

flanking arrangements now exist. Where old masonry works are available, they will be measurably serviceable, even with their present armament (usually 10-inch and 8-inch Rodman smooth-bores); for a heavy fire of canister, grape, shrapnel, and shell is as effective now as it ever was against launches and small craft, which, if permitted to countermine, would work the worst damage to the mines. Such vessels abound in every fleet, and provision to meet them is to be considered first. A few of the converted 8-inch rifles now on hand, judiciously distributed among the old forts, may prove serviceable against regular counterminers.

Probably the idea will suggest itself to every one that to depend on the old works to cover the flanking guns of the mines is to rest on a broken reed; because they can be so easily breeched from a distance by the fleet, and because, under such a fire, the cannoniers would be driven from the guns. But it must be remembered that countermining is most to be dreaded at night, when little can be accomplished by distant fire; and that by day the ships, while attempting to destroy the old works, will be themselves subjected to the deliberate practice of the high-power guns. Experience leads me to believe that a heavy artillery fire upon an enemy's field battery will be sure to compel a reply, and I see no reason to doubt that the same is true on shipboard. Some of the flanking guns would doubtless be placed *hors de combat* by occasional shots, and sometimes the temporary withdrawal of the cannoniers will doubtless be expedient; but whatever be the demerits of the old stone forts, a deficiency in number of guns is not one of them. They swarm on every front, and particularly on those not visible to the enemy at a distance, from which their fire to flank the mines will largely be required. The problem to destroy at long

ranges the efficiency of every one of scores of flanking guns, while suffering from the fire of high-power guns, will, I think, be neither simple nor satisfactory to the attacking party. Judging by the precision of fire shown at Alexandria, the enemy will be *hors de combat* before it is accomplished; and while even a few of the guns can be served his fleet of launches must remain idle. While forts of this type will never be constructed in the future, they can still be made use of in the plan of defence to-day; and to condemn them entirely is, in my judgment, a very great mistake.

Where new works are to be constructed, whether for the flanking of mines or for repelling boat parties attempting to land, so much use will be made of the latest type of small ordnance that I shall give a brief summary of some particulars which have an important bearing on land defences, even at the risk of recalling facts familiar to every one present.

The machine guns of Gatling, Gardner, Nordenfelt, and Maxim usually fire bullets of 0.45 inch calibre, although Nordenfelt and Maxim both supply patterns firing 1-inch steel projectiles. The rapidity with which the small calibres can be served ranges from 600 to 1 200 rounds per minute; they were designed to replace infantry fire, but are now regarded as better suited for defending positions than for active field service. The Nordenfelt and Maxim inch bolts were designed to pierce the light armor of torpedo-boats. The Maxim 0.45-inch projectiles are fired automatically at the rate of 660 per minute, and his inch bolts at the rate of 280 per minute; the latter pierce an inch of iron at 100 yards.

Hotchkiss revolving cannon are made of calibres 37 mm. (1-pounder), of 47 mm. (3-pounder), and of 53 mm. (4-pounder). They fire shells designed to replace light-artillery projectiles up to a range of at least

2 000 yards (extreme range 5 000 yards). Served at full speed, the smaller calibres have attained a rate of 600 shots per minute, and, when aimed, of 17 shots per minute. A special flank-defence pattern (40 mm.) is designed for sweeping ditches. The five barrels are rifled on different pitches, ranging from 1 to 6.7 turns, which enables them to distribute 1 500 projectiles per minute with admirable uniformity and without change of aim, over a space 300 yards long and 50 feet wide.

Rapid-firing hand-loaded guns are especially designed for repelling the attacks of torpedo-boats, and they will play an important part in flanking mined zones. The Hotchkiss Company fabricates them upon modern high-power principles, 32 to 34 calibres long. About 1 200 yards is their fighting range, their rapidity of fire varying from 20 to 10 shots per minute, according to the care with which they are aimed. Very gives the following as their steel-penetrating power :

Calibre 37 mm., or 1-pounder: 0.8 inches at muzzle ; 0.4 inches at 1 200 yards.
Calibre 47 mm., or 3-pounder : 1.7 inches at muzzle ; 0.8 inches at 1 200 yards.
Calibre 57 mm., or 6-pounder : 3.5 inches at muzzle ; 1.75 inches at 1 200 yards.
Calibre 65 mm., or 9-pounder : 4.0 inches at muzzle ; 2.25 inches at 1 200 yards.
Calibre 100 mm., or 33-pounder : — inches at muzzle ; — inches at 1 200 yards.

Iron penetrations are one-third greater. These guns all fire steel shells, common shells, shrapnel, and case or canister. The three smaller calibres have non-recoil mounts, and the others recoil mounts ; they are also sometimes mounted on a modified casemate carriage, or like field artillery.

The Elswick Company is now fabricating a 4.7-inch 30-pounder pattern which has a muzzle velocity of 1 900 feet per second, and which can be fired at the rate of 10 shots per minute; and designs for a 70-pounder have been completed. Should this gun prove successful a very important departure in light cannon of high power may be at hand.

Rapid-firing guns are also receiving attention at Essen. A 15.5-pounder was tested last February which gave a muzzle velocity of 1 990 feet per second and a rapidity of 22 shots per minute.

These machine and rapid-firing guns have all come into general use since our civil war, but they are now universally adopted. When skilfully applied they will be of great service in meeting our needs resulting from widely distributing batteries in Coast Defence.

**Magazines.**—Magazines, of course, are always placed, so far as possible, out of sight of the enemy, and where his projectiles cannot penetrate. The latter condition is far more difficult to fulfil than formerly, and the problem often becomes perplexing. The Royal Engineer rule a few years ago required 18 feet of granite or other masonry; but they now allow 40 feet, and Captain Lewis states (1884): "It is probable that for the immediate present the 40 feet of protection aimed at with our magazines is sufficient, but it will not be so for long."

With turrets, casemates, and lifts, and at contracted sites, the natural place for magazines is in a tier of casemates under the guns. They should always be buried under ground when practicable.

The usual rule for capacity is based on having 100 rounds of cartridges and 100 rounds of shell on hand, and not more than four guns are allotted to one service magazine.

In future permanent magazines no attempt will

be made to preserve the powder dry by excluding moisture from the room. Experience has shown that this is impossible to accomplish in many cases; and, moreover, the huge size of modern charges will forbid their preparation at the time of firing. The cartridges must be put up in advance, and in water-proof cases which will serve to keep them dry indefinitely.

The necessity of precautions to prevent the accidental explosion of a cartridge *en route* to the gun from communicating fire to the magazine, is receiving attention abroad. Safety-traps in lifts and swinging mantelets in magazine passages are recommended; also that no more wood-work about a cartridge-lift than is absolutely necessary should be allowed.

No greater disaster can occur during a bombardment than the explosion of a large magazine. Two land batteries were silenced from this cause at Lissa in 1866, and two at Alexandria in 1882. The surrender of the Castle of San Juan d'Ulloa to the French fleet in 1838 was due to a like catastrophe. At the storming of Fort Fisher, N. C., in January, 1865, a shell from a 15-inch naval gun reached and crushed the plank sheathing of the large traverse magazine at the principal salient near the Blakely rifle; and had the fuse done its duty many lives lost in the subsequent assault might have been saved. It is safe to assert that provisions to prevent such accidents in future will engage the attention of the Engineers of every Nation.

# FOURTH LECTURE.

## MORTARS AND SUBMARINE MINES.

Vertical fire; advantages of rifling; carriages and platforms; mortar batteries; economy of mortars—Submarines mines; general conditions; attacks by daylight; attacks by night or in fogs; attempted passage by force.

THE introduction of armored ships of war, besides increasing the calibre of land guns and modifying the nature of their carriages, of their mountings, and of their cover, has brought into so much greater prominence two old elements of coast defence that it may almost be said to have created them. I refer, of course, to vertical fire and to submarine mines. These modes of counter-attack directly assail what is now, and what must continue to be, the most vulnerable parts of the ship—her deck and her bottom. They have another peculiar merit: their attack admits of no reply in kind. They are weapons which cannot be used by ships against forts, except mortars in occasional river operations like the bombardment of Fort Jackson, below New Orleans. With vertical fire, the least roll of the sea or the least swinging to the anchor must be fatal to anything like precision.

For these reasons I suppose a discussion of mortars and submarine mines, rather more elaborate than has been given to the use of guns, may be of interest to Naval Officers.

### VERTICAL FIRE.

For the defence of our entire coast the Fortification Board of which Secretary Endicott was presi-

dent, endorsing the views held by the Board of Engineers, recommended 581 high-power guns of all calibres, and 724 heavy mortars, or, as they are now often called, rifled howitzers. The proportion between the number of guns and mortars shown by these figures differs so enormously from that accepted by the best authorities a quarter of a century ago, that the reasons for the change demand consideration.

They are, in brief, (1) Because the blow is struck precisely where armored protection is least effective, and where either shot or shell are most destructive in their effects. Indeed, in their power of encountering such missiles ships have retrograded since the close of the civil war, when it was proposed to give the *Kalamazoo* a solid deck throughout of three inches of wrought iron strongly supported. Now the tendency seems to be to sink the protected deck below the water-line, and thus to provide a shell-trap where the effect of the explosion will be increased to the maximum by confinement. In plunging fire the mortar trajectory is incomparably more effective than that of cannon. The latter, with the gun at a height of 100 feet, attains an angle of incidence of 10 degrees only at a two-mile range, and at a height of 500 feet only at a mile-and-a-half range; and this with low-power guns. Modern high-power guns have still flatter trajectories, and are therefore still less fitted for effective plunging fire. (2) Because of the greatly increased precision of modern vertical fire resulting from the introduction of rifling, from improved systems of range-finders, and from a disposition and mode of mounting which devolves the responsibility of aiming upon a single officer stationed where he can accurately watch the effect of his shots and correct errors as soon as they occur. Formerly this responsibility fell upon the individual gunners, who were often annoyed by smoke and confused by the

fall of projectiles other than their own around the target—a difficulty aggravated by the long time of flight as compared with that of guns. (3) Because vertical fire cannot be silenced, even on land, when the mortars are properly covered. The artillery contest at the digging of the Dutch Gap Canal on James River in 1864 is a case in point. The excavation, across a narrow neck between two bends, covered an area of 30 000 square feet, being 500 feet long by 60 feet wide. The bank opposite the upper end of the cut, held by the enemy, was low; that opposite the lower end, held by us, was a bluff probably 80 feet above the water. Moreover, a signal-tower, 120 feet high, on this bluff, gave an excellent opportunity to overlook the whole ground, the river here being only 400 yards wide. To interrupt the digging of the canal, the enemy placed in front of it, at ranges varying from 600 to 800 yards, four or five siege-mortars in sunken batteries concealed behind clumps of trees and provided with bomb-proof cover. Their fire sunk the dredge and harassed the working parties; and to compel their silence became an important object. Seven siege-mortars and five guns were placed in position near the cut, where they had a cross-fire at short range; and a skilful officer, Captain Pierce, First Connecticut Artillery, fired about 4 000 shots, taking advantage of the tower to direct his aim, and of the guns to prevent the Confederate cannoniers from watching the effect of their firing. He interfered with their practice, but he *could not compel their silence.* This duel, and much other firing at Petersburg, convinced me that a mortar battery, well placed, well constructed, and well served, cannot be silenced. If this be true in respect to a land attack, how much more true is it in respect to a naval attack, where no target is presented for horizontal fire, and where vertical fire is not to be

feared! In fine, ships may sometimes compel the silence of land guns, but they must endure vertical fire so long as they remain within range. (4) Because of the relatively small cost of mortars, as compared with that of guns, both for fabrication and for cover against an enemy's fire. This advantage permits them to be used in large numbers without exorbitant demands upon the Treasury. Some of these points will bear elaboration.

**Advantages of Rifling.**—The trajectory of projectiles fired under high angles differs materially from that of ordinary gun practice; and to appreciate the effect of rifling mortars this difference must be understood. Fired with an elevation of, say, 45 degrees, the shell receives an initial velocity which can be resolved into two equal components, one horizontal and the other vertical. Both components will be gradually reduced by the resistance of the air (acting nearly in proportion to their squares), but the vertical component is also directly opposed by gravity, which soon brings it to zero. This will occur near the highest point of the trajectory. Gravity, still acting, will then communicate a velocity in the reverse direction, which will increase proportionately to the square roots of the distances passed over, until the resistance of the air, making itself felt more and more, will at last establish an equilibrium, and the component will become unvarying. The name "final velocity" is usually applied to this, the maximum theoretical velocity which can be used against a ship. Unfortunately, from an engineer point of view, its value is not great, being for a 10-inch round shot, 580 feet; for a 15-inch round shot, 700 feet; and for a 20 inch round shot, 790 feet. These values are theoretical limits which can never be reached, although they may be approached in long-range practice.

The vertical component has so small an average

value that, within the limits of ordinary firing, the laws applicable in vacuo give results differing but slightly from exact accuracy. Hence, within these limits, the vertical velocity of impact of a mortar projectile may be assumed to be that which would be acquired by a heavy body falling in vacuo a height equal to one-fourth of the horizontal range in feet. At elevations above 45 degrees, the charge remaining the same, the height attained is greater and the range is less; and hence, *in obtaining a given range*, the useful component of the velocity is doubly increased. At 60 degrees elevation the height is one-half greater and the range is one-tenth less, and at 75 degrees elevation the height is four-fifths greater and the range one-half less than at 45 degrees.

From these well-known laws the following approximate rules result for estimating the vertical velocity (in feet per second) of mortar projectiles at impact, the firing being done at the water level. This vertical component of course measures the effective velocity upon which deck-perforation depends.

At 45 degrees elevation the vertical component is four times the square root of the range in feet.

At 60 degrees elevation the vertical component is 4.9 times the square root of the range in feet.

At 75 degrees elevation the vertical component is 5.3 times the square root of the range in feet.

Having thus formed an estimate of the effective velocities attainable at different high angles and at different ranges, the next point to be considered is the energy necessary to accomplish the perforation of the deck.

Actual experiments in this direction with vertical fire are few in number. One fact noted by General Duane at the attack on Fort McAllister throws some light on the subject. A 10-inch mortar-shell, loaded with sand and thrown by the fort at a range of about

1 800 yards, just penetrated the deck of one of our monitors, which was plated with 1.5 inches of iron. Assuming that the shell weighed 100 pounds, and that it was fired at 45 degrees elevation, its vertical energy at impact was about 1.9 foot-tons per inch of its circumference. A 13-inch shell fired under like conditions would have had 3.1 foot-tons, and would probably have endangered the vessel.

Trials in England, about 1871, proved that a 13-inch mortar-shell at 4 200 yards would easily penetrate a strong deck covered with 1.5 inches of wrought iron under 4.5 inches of wood planking (energy, 7.1 foot-tons per inch of circumference); and that at 2 800 yards it would penetrate a similar deck covered with one inch of wrought iron under 4.5 inches of wood planking (energy, 4.7 foot-tons per inch of circumference).

In the absence of experimental data derived from modern vertical fire, recourse must be had to the behavior of plating when tested in the ordinary manner. It is most convenient to assume wrought iron as the basis of comparison, because its resistance is governed by more definite laws than that of any other kind of armor; and, although the different formulæ representing these laws are not entirely accordant, they are fairly so for small penetrations. They indicate that to pierce three inches of wrought iron requires from 12.5 to 14.5 foot-tons of energy per inch of the shot's circumference. But this energy for a falling projectile is:

$$E = \frac{WV^2}{2\,240 \times 2g \times 2\pi R} = \frac{WV^2}{906\,000\,R}$$

This formula shows, since $V$ is a function of the range and pointing, that when these are fixed the only way to increase the energy at impact is to increase the weight relatively to the radius. But this is precisely the effect of rifling; and herein lies the

first advantage resulting from its use. For example, the weight of a 12-inch solid shot is about 215 pounds; that of the corresponding elongated projectile is about 625 pounds. Here, therefore, is a gain of nearly 200 per cent. in the effective force of impact—a gain which, by reason of the low velocities inherent to vertical fire, is of great importance. It may even be increased at short ranges, if deemed expedient; Krupp fires a projectile weighing 759 pounds from a 28-centimetre (11-inch) howitzer at 58° elevation.

The following table exhibits the destructive energies of a service 12-inch rifled-mortar projectile fired at different angles and ranges. It illustrates one characteristic difference between horizontal and vertical fire: with the former we must shorten the range and lessen the elevation, and with the latter we must lengthen the range and increase the elevation, to increase the destructive effect.

FALLING ENERGY OF A 12-INCH 625-LB. RIFLED PROJECTILE.

| Range. | Foot-tons per inch of circumference. | | |
|---|---|---|---|
| | Elevation 45 degrees. | Elevation 60 degrees. | Elevation 75 degrees. |
| Half-mile | 4.9 | 7.3 | 8.5 |
| One mile | 9.7 | 14.6 | 17.1 |
| Two miles | 19.4 | 29.2 | 34.1 |
| Three miles | 29.1 | 43.7 | 51.2 |
| Four miles | 38.9 | 58.3 | 68.2 |
| Five miles | 48.6 | 72.9 | .... |

As already stated, it requires from 12.5 to 14.5

foot-tons per inch of the shot's circumference to penetrate a 3-inch wrought-iron deck. Hence at a range of one mile and upward the fire becomes dangerous.

The second merit of rifling is that it vastly increases the serviceable range. With the old smooth-bore 13-inch mortar the full charge was 20 pounds, giving a range of 4 200 yards, of which not more than 2 200 yards were effective against a 3-inch deck. With the 12-inch rifled mortar these figures are 60 pounds and 9 000 yards, of which 7 200 yards are effective. Here, therefore, we have a gain of 325 per cent. It is this merit that makes the new mortar so useful in opposing the distant bombardment of cities by modern high-power guns on shipboard. No admiral would expose his ships to receive such blows on their decks without serious concern; and, as will soon appear, all we have to do is to multiply numbers and provide suitable emplacements to obtain an occasional hit, even at very long ranges.

But this suggests the third advantage of rifling—increased precision of fire. It would at first sight appear paradoxical that rifling can be beneficial with this class of ordnance. As used in guns it tends to keep the axis of the projectile always parallel to itself. But in vertical fire this would make the shell fall sideways, which, by increasing the resistance of the air, would reduce the vertical velocity, and by opposing an unsymmetrical shape would probably cause an irregular flight. But experience, the only sure guide in such matters, proves these anticipations to be groundless. About a dozen years ago experiments were made at Shoeburyness to test the matter. A large target was inclined at such an angle as to receive the trajectory at right angles to its plane; and it was perforated by a round hole, not by one shaped like the longitudinal cross-section of the projectile, as would have been the case, to a greater or less ex-

tent, if the axis had remained parallel to itself. A little flag was then placed in the open fuse-hole, and the spectators could distinctly perceive that the axis remained nearly parallel to the trajectory. Knowing the fact, it appears probable that the short length of the bore in the mortar limits the velocity of rotation just sufficiently to prevent tumbling, but not enough to prevent the resistance of the air from forcing the projectile to turn to a position of tangency. However this may be, nothing is more certain than that precision of fire has been vastly increased by rifling, as will appear from the following statement:

During the civil war 268 shots were fired in the Defences of Washington, at a range of about half a mile, to determine the precision of fire of smooth-bore siege-mortars in the hands of good troops, under fair service conditions. It was found that with the 10-inch mortar the average distance from the point of impact to the centre of the target was 40 yards, and that six-tenths of the shells fell within this radius. With the 8-inch mortar these numbers were 50 yards and five-tenths of the shells respectively. With the 24-pounder Coehorn mortar (for which this range is too great) about half the shells fell within 80 yards of the centre of the target. With mortars, as with guns, the accuracy of fire increases with the weight and density of the projectile; and it was estimated that, with proper care, a 20-inch smooth-bore mortar would throw at least half of its projectiles within 30 yards of the centre of the target at a range of 1 000 yards: *i.e.*, the chances should be even that the shell will fall within a circle of which the area is 26 000 square feet. But the area of the deck of modern war-ships varies between about 4 000 and 16 000 square feet, the mean (250 by 50 feet) being about 12 500 square feet. Hence, by the theory of probabilities, about one out of eight 20-inch mortar-

shells (smooth-bore) should strike her at 1 000 yards from the battery ; at 2 000 yards her danger would not be very materially reduced ; at 3 000 yards the uncertainty of fire would so much increase that it was estimated that not more than one shot in twenty-five would take effect. Let us now see how these figures compare with the results to be expected from the modern 12-inch rifled mortar.

At the Bucharest experiments of 1885–86 some valuable data were obtained as to the precision of fire of Krupp's 21-centimetre siege-mortar. The range was 2 761 yards, or a little more than a mile and a half. The charge was 6.6 pounds of powder. The projectiles were either common shell weighing 200 pounds, or steel shells weighing the same but longer and carrying a larger bursting charge (24 pounds instead of 10.5 pounds). The elevation varied between 53° and 56°.5.

Two mortars were used : 70 shell were fired at the French cupola, and 94 at the German. The firing occurred on four days, that at the French cupola coming first. The following figures show separate analyses, an evident improvement taking place during the practice :

| | FRENCH CUPOLA. | GERMAN CUPOLA. |
|---|---|---|
| Extreme lateral dispersion.. | 273.4 yds. | 76.5 yds. |
| Extreme dispersion in range. | 393.7 " | 273.4 " |
| Average lateral dispersion.. | 16.2 " | 9.7 " |
| Average dispersion in range. | 44.2 " | 39.5 " |

Out of these 164 shells, 70, or nearly one-half, fell within a rectangle around the target of which the area was about 17 000 square feet (20 x 80 metres). Hence, the area of the deck being 12 500 square feet, about one projectile out of five or six fired from this siege-mortar at a range of 1.5 miles should strike a modern war-ship at anchor. The exact percentages, computed by the theory of probabilities, are, for the head-on

position 17½ and 30½ per cent., and for the broadside position 11½ and 14 per cent. respectively.

With mortars large enough to be used in coast defence experimental data are not so full as could be desired, because the firing has not been made under service conditions. The chief causes of bad practice are to be attributed: (1) to mechanical inaccuracies in the mortar and carriage; (2) to want of uniformity in the ammunition; (3) to errors in pointing; (4) to wind and other unfavorable conditions; (5) to the excitement of action—although to this last little weight should be accorded in mortar practice against shipping, for the gunners will be covered so perfectly against any return that the veriest coward should remain cool.

Precise data are available to estimate the effect of the first-named causes of inaccuracy (mechanical defects and variable ammunition) in Krupp's tables of firing at Meppen:

GERMAN PRACTICE WITH 28-CENTIMETRE (11-INCH) HOWITZER.

| DATE. | Number of shots. | Elevation. | Charge. | Projectile. | Range. | EXTREME DISPERSION. | | MEAN DISPERSION. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Longitudinal. | Lateral. | Longitudinal. | Lateral. |
| | | ° | lbs. | lbs. | yds. | yds. | yds. | yds. | yds. |
| Mar. 30, 1887. | 5 | 58 | 13 | 506 | 1 993 | 36 | 5 | 11.9 | 1.6 |
| July 9, 1886. | 5 | 58 | 19 | 759 | 2 158 | 13 | 13 | 5.4 | 3.3 |
| June 28, 1886 | 8 | 58 | 33 | 759 | 4 019 | 46 | 15 | 13.0 | 4.7 |
| Mar. 14, 1879. | 10 | 45 | 42 | 475 | 8 513 | 145 | 24 | 35.0 | 4.5 |
| May 14, 1886. | 10 | 45 | 62 | 475 | 10 787 | 130 | 54 | 36.2 | 10.4 |

Applying the calculus of probabilities to the last

two records, it appears that nearly one rifled shell out of two (65 per cent. in the head-on position and 15 per cent. in the broadside position) should strike the deck of a war-ship at a range of 4.8 miles; and that nearly one out of four (31 per cent. in the head-on position and 14 per cent. in the broadside position) should take effect at a range of 6.1 miles. These figures, of course, give an exaggerated idea of what can be expected in service, because the other causes of inaccuracy above named are ignored. What numerical coefficient should be adopted to correct for these omissions is a matter of individual judgment.

The following are some results of experimental firing with an 11-inch mortar in Russia in 1885. The principal objects were the testing of new carriages, and the determination of the maximum charge under the condition that the pressure in the bore should not exceed 1 900 atmospheres. These charges were fixed, after firing 400 rounds with full and 200 with reduced charges, at 46.9 pounds with a cast-iron projectile weighing 477 pounds, and at 45 pounds with a steel projectile weighing 559 pounds, the grade of powder being "large grain." I give the table showing the abstract of this firing in full, because it illustrates a subject concerning which little information is accessible:

RUSSIAN PRACTICE WITH 11-INCH MORTAR.

| PROJECTILES. | Weight of projectile. | Weight of charge. | Initial velocity. | Pressure at base of bore. | Range at 43° 30′. | Probable deviation. In range. | Probable deviation. In direction. |
|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | feet. | atmos. | yds. | yds. | yds. |
| Cast iron...... | 477 | 36.1 | 758 | ........ | 5 668 | 24.0 | 4.4 |
| " ...... | 477 | 46.9 | 938 | 1 875 | 7 412 | 28.3 | 6.5 |
| Steel.......... | 559 | 18.0 | 482 | ........ | 2 343 | 17.6 | 3.3 |
| " .......... | 559 | 27.1 | 613 | ........ | 3 597 | 13.2 | 2.2 |
| " .......... | 559 | 36.1 | 735 | ... ... | 5 014 | 19.8 | 3.3 |
| " .......... | 559 | 45.1 | 840 | 1 700 | 6 431 | 26.2 | 4.4 |

The wonderful precision attained in this practice proves that the Krupp firing analyzed above was not exceptional, and the same conclusion is warranted by recent records of firing with a 12-inch mortar at Sandy Hook. It must, therefore, be admitted that modern improvements in vertical fire have kept pace with those in guns. Indeed, in a recent analytical accuracy table it appears that the probability of hitting, with the projectiles of a 9-inch mortar, a first-class ship of war lying at a known distance diagonally to the plane of fire, is 62 per cent. at 1.3 miles, 51 per cent. at 2.6 miles, and 32 per cent. at 4.0 miles. In other words, it is about half that of hitting the same ship with a rifled gun of similar calibre.

These results of the practice ground are not without confirmation in actual service. On May 10, 1877, a Russian shell from a 6-inch rifled mortar (one of four in position near Braila, on the Danube) "penetrated the deck of one of the largest Turkish monitors, the *Lufti-Djelil*, and exploded in the powder-magazine. She blew up and sank instantly, with all her crew of 17 officers and 200 men. The ship was a twin-screw, iron-clad, sea-going monitor, carrying four 150-pounder Armstrong guns."

The latest development in mortar practice is the reported ability to throw large explosive charges of wet gun-cotton. It is stated on good authority that in Germany shells containing 110 pounds are now fired with safety from a 28-centimetre mortar. If this claim be verified it marks an important advance; because the long range of the piece will enable it to throw its projectile beyond the mined zones, and thus avoid the objection fatal to the pneumatic dynamite gun that it assists the enemy in countermining.

**Carriages and Platforms.**—No better evidence can be desired of the low estimate which until within a few years has been placed upon the value of vertical fire than the crude mode of mounting universally

adopted. Every practical requirement of precision was ignored; hence, in my judgment, the small part which mortars formerly played in projects for sea-coast defence. Since their value has been better understood, the old mortar bed with its eternal "heave, heave, heave," and the absurd pointing-cord and old wooden quadrant, have disappeared, and artillerists everywhere are giving intelligent consideration to the subject. It is now appreciated that so long as every gunner must point his piece independently, the slow flight of the projectile will prevent him from recognizing the splash of his own shell from those of others; and hence the more numerous the mortars the worse will be the firing.

All this is changed in the new system. Mortars are now mounted upon chassis like guns, and the traverse-circle is graduated so that they can be accurately pointed in any desired vertical plane. The zeros of graduation for the entire group to be served together are given the same relative position with respect to the meridian, so that all can be set to fire in any desired set of parallel planes. By this system the captain regulates every shot; and if the mortars are all loaded with equal charges, set at equal angles of elevation, and adjusted to the same azimuth, the shells should fall, simultaneously if so desired, over an area not greatly larger than that of the battery itself.

One curious fact, which has a bearing upon the practicability of firing at high angles on board ship, has been developed quite recently in experimenting with new mountings. The increase of weight in projectile and charge has so largely increased the shock on the carriage, and especially on the platform, that radical changes are demanded.

Thus some recent experiments in Italy, conducted by the Artillery and Engineer Committee with a 28-centimetre (11-inch) howitzer mounted on an ordinary carriage, with a charge of 42 pounds of powder and

elevations varying from 30 to 60 degrees, have proved that the shock transmitted to the platform is surprisingly difficult to resist. A platform of granite, 24 inches thick, laid on a substratum of concrete 3 feet thick, was soon cracked and thrown out of level. A second platform, covering a wider area of concrete and with larger granite blocks, better distributed, shared the same fate. The third trial was with a bed introducing an elastic element. Upon the concrete foundation was placed a layer of granite 16 inches thick; upon this was laid a double layer of oak beams, each 10 inches thick; upon this was a layer of cast-iron plates, 4 inches thick, with bevel joints. Even this structure developed injurious cracks and settling, although still serviceable after 244 rounds. Finally, for the fourth trial, a platform identical with the last received an additional top layer of 1.5 inches of wrought-iron plates. This structure endured the firing of 1 225 rounds without becoming unserviceable, and was approved for adoption.

But the use of wood in the construction of permanent works has always been regarded with disfavor by Engineers, and it is quite natural to find, as we do, that efforts are making to introduce the element of elasticity in some other way. It is now sought to modify the carriage in such a manner as to reduce the shock on the platform; and two different patterns, one by the Elswick Ordnance Company and the other a Russian device by Lieutenant Raskasoff, are under trial.

The Elswick pattern has yielded so favorable results with a 28 centimetre (11-inch) howitzer at Spezzia that the Italian government is reported to have decided to order a large number for service. The principle is to break the shock of recoil by interposing an elastic buffer. The chassis-rails slope to the rear at an angle of 60 degrees to the horizon. The top carriage, resting thereon, is supported by two hydro-

pneumatic buffers fixed below and in prolongation of the chassis-rails. Each cylinder contains two chambers, connected by a valve which can be regulated from without. One chamber is filled with glycerine and receives the recoil ram; the other contains a supply of glycerine and air. When the howitzer is fired the force of recoil drives the rams into their chambers, and, displacing the columns of glycerine, forces it out through non-return valves into the outer chambers. This increases the normal tension of the contained air and glycerine from 750 pounds to 1 150 pounds to the inch. To raise the carriage again to the firing position the valve is opened between the cylinders, and the equalization of pressure thus effected does the work. The whole carriage, mounted on a live ring, is readily turned to any desired azimuth by ordinary training gear. Facilities for bringing the axis of the piece to a horizontal position for convenience in loading are provided. The axis of the howitzer can be raised or lowered 15 degrees from its mean elevation of 60 degrees in firing, thus permitting of elevations ranging from 45 to 75 degrees. The carriage supplied to the Italian government is said to be adapted to receive an 11-inch howitzer.

The new Russian carriage is similar in principle to that of the Elswick Company, but, instead of the hydro-pneumatic apparatus, use is made of an hydraulic cylinder and a system of steel-disc springs. It has been adapted to an 11-inch mortar made on the Krupp system and 12 calibres long. The action is entirely automatic. The Committee desire to combine low as well as high angles of fire, and thus are compelled to sacrifice some advantages peculiar to each. The chassis-rails slope to the rear at an angle of only 35 degrees. The carriage admits of an extreme elevation of 25 degrees above this sloping plane, or of 60 degrees as referred to the horizon. The extreme recoil is said to be about two and a half

feet. Several hundred rounds have been fired without injury to a pattern of platform which with an ordinary carriage was completely shattered.

It is quite certain that modern mortars will require some such mounting as has just been described, and I think few matters connected with our new land armament are more urgently in need of attention. The Ordnance Department is alive to the necessity, and it is to be hoped that Congress will soon provide means for making the trials. With the old form of carriage, or with any form which does not provide a buffer, our Engineers will probably be forced to introduce wood into the platforms. But, although experiments have been made in this direction with creosoted timber, no success has been had in preventing decay when exposed for long periods; and in all probability the outbreak of war would find such platforms either unlaid or unserviceable.

**Mortar Batteries.**—In these days, when Engineers are compelled to deal so much with the terrific energies of modern horizontal fire, it is a relief to find one kind of effective ordnance which can be mounted and served with almost absolute safety from behind a simple earthen parapet. No embrasures with their conflicting conditions are to be devised, and an ample thickness of earth is all that is needful. But even this statement does not present the case with sufficient strength. The battery may be entirely concealed from the enemy—indeed, would usually be so concealed by natural inequalities of the ground, or by bushes or trees. Even a view of the ship from the battery itself is unnecessary, for the fire will always be regulated from a distant point. In a word, with the smoke of our firing as the only target for hostile guns, and with vertical fire (not to be had on shipboard) only to be dreaded, it is easy to understand why mortar-batteries are simple as compared with all others.

There are, however, certain matters which must not be ignored. In order that the projectiles shall fall sufficiently near together to make the fire effective, it is essential that the mortars shall be massed, thus constituting, as it were, a single piece. Four mortars may be placed in one pit, and by disposing four of these pits symmetrically round a common centre very convenient arrangements for serving are secured. A compact battery containing 16 mortars logically results from this reasoning, and that number is suitable for the command of a single officer. Such a combination constitutes, in effect, a single gigantic musket throwing a charge of buckshot of which each pellet weighs a quarter of a ton!

The radius of the circle is fixed by the following considerations: On the one hand, the lateral and longitudinal separation of the pits must be sufficient to afford space between them ample for magazines, loading-rooms, and bomb-proof cover for the garrison. On the other hand, the extreme distance between pits must be limited to the extreme dispersion of the projectiles of a single mortar, else there will be an area of safety in the middle of the field of fall. Lateral dispersion being much less than longitudinal dispersion, this condition fixes a much narrower limit for admissible separation of the pits in a direction across the plane of fire than in a direction parallel to that plane. Indeed, in the former direction the extreme limit can hardly be avoided; but in the latter it is easy to secure a decided overlapping of the rectangles.

These conditions are fulfilled when the centres of the outer mortars in each pit lie on a circle 150 feet in radius, the extreme lateral separation being 140 feet, and the extreme longitudinal separation being 265 feet.

The arrangements in the battery are simple. One long bomb-proof extends parallel to the usual plane

of fire, with debouches into each pit near its extremities; the magazines, shell-rooms, engine-rooms, etc., are placed under the cross-embankment, with communications opening into the middle of the central bomb-proof. The firing will all be done by electricity from the bomb-proof, permanent leading wires to the mortars being laid in advance; all the work of loading, except the actual insertion of the shells in the mortars, will also be done under cover; the cannoniers will be exposed only when loading; and, lastly, nothing but accident can bring a hostile shell to interrupt the steady prosecution of the firing.

The service of such a battery in action would be something like the following: The captain would take his station at a point from which he could see the enemy engaged at some work, as, for example, at countermining in our mined channel. From his chart and a position-finder he would determine the elevation, charge, and azimuth for a trial shot. Giving his orders by telephone, he would watch the splash of the shell, and, estimating the deviation, would give orders for the second shot accordingly. Having succeeded in dropping one shell in close vicinity to the enemy, he would order the whole battery to adopt the same elevation, charge, and azimuth, and to fire by volleys of 4 or of 16 mortars, as seemed best. After that, countermining, which to be effective must be strictly local, could be carried on only under great disadvantages; and even in an attempted distant bombardment the only safety for the fleet would lie in so frequent a change of position as to destroy any precision of fire.

To fix ideas upon the probable distribution of the projectiles from such a battery containing sixteen 12-inch rifled mortars, I have discussed the foregoing German and Russian data with 11-inch mortars, which afford the best available criterion for judging of the performance of the latest sea-coast types. The

two records are remarkably accordant; and, combining those at 4.8 and 4.2 miles (8513 and 7412 yards) as of equal weight, they give the following results when discussed by an application of the method of least squares.

The 16 projectiles, being fired under identical conditions, should fall in relative positions corresponding to those occupied by the mortars themselves. But the units of each sub-group of four, being situated at the angles of a square only 20 feet on the edge, may be treated as a compound unit in the computation. The mean rectangle containing half of the projectiles of a single mortar, derived from the combined records, is 28 feet wide and 162 feet long in the plane of fire. Hence, by the law of error, the following rectangles result:

PERCENTAGE RECTANGLES IN MORTAR PRACTICE AT 4.5 MILES.

| Zone. Per Cent. | Length. Feet. | Width. Feet. | Area. Sq. Feet. | Receives Per Cent. |
|---|---|---|---|---|
| 20 | 62 | 11 | 653 | 4 |
| 40 | 126 | 22 | 2 103 | 16 |
| 60 | 202 | 35 | 4 332 | 36 |
| 80 | 308 | 53 | 9 287 | 64 |
| 100 | 648 | 112 | 56 201 | 100 |

An over-lapping tinted diagram is next prepared, showing these rectangles in their proper relative positions; and the number of projectiles, in a volley from four mortars, falling in 1 000 square feet of each tint is inscribed thereon. By placing a tracing of the *Inflexible*, also subdivided into sections of 1 000 square feet, in any desired position on this diagram, it is easy to estimate her danger, and to form a definite idea of the degree of

precision which is needful in the officer's determination of the locus of the ship when directing the firing.

The following results have been reached by this method. To define the different positions occupied by the middle of the ship, they are referred to a rectangular system of co-ordinate axes, parallel to the sides of the rectangles of dispersion and central to the field of fall. In the "diagonal" position the keel of the ship makes an angle of 45 degrees with the axis of X. The shots per hour are computed upon the supposition that six volleys are fired, which is certainly within what may reasonably be expected. The range, it will be remembered, is about four and a half miles.

PROBABLE PRACTICE AT THE *INFLEXIBLE* WITH 11-INCH MORTARS AT 4.5 MILES.

| Position of the Ship. (feet) | | Hits per Volley. | Hits per Hour. | Effective per cent. of Shots. |
|---|---|---|---|---|
| Head on. | Central | 0.93 | 5.6 | 5.8 |
| " | X = 60; Y = 0 | 3.24 | 19.4 | 20.3 |
| " | X = 60; Y = 122 | 2.84 | 17.0 | 17.8 |
| Broadside. | Central | 2.21 | 13.3 | 13.8 |
| Diagonal. | Central | 2.24 | 13.5 | 14 0 |
| " | X = 50 ; Y = 0 | 1.87 | 11.2 | 11.7 |
| " | X = 100 ; Y = 0 | 1.40 | 8.4 | 8.8 |
| " | X = 150 ; Y = 0 | 0.69 | 4.1 | 4.3 |
| " | X = 0 ; Y = 100 | 2.27 | 13.6 | 14.2 |
| " | X = 0 ; Y = 200 | 1.69 | 10.1 | 10.5 |
| " | X = 0 Y = 300 | 0.82 | 4.9 | 5 1 |
| " | X = 0 ; Y = 400 | 0.33 | 2.0 | 2 1 |
| " | X = 0 ; Y = 500 | 0.07 | 0.4 | 0 5 |

From this table it appears that the fire of this battery, when armed with 11-inch mortars, covers a space 800 feet long and 300 feet wide so effectively, at a range of four and a half miles, that the *Inflexible*, within its limits, would probably be struck from two to nineteen times per hour.

It is, of course, to be understood that computations of this character afford only approximate indications of what can be attained in service; but they do show that with this form of battery slight errors in adjusting altitudes, azimuths, and charges will have far less effect than when the same number of mortars are pointed and served separately. The combination of several somewhat erratic projectiles in one volley tends to eliminate individual lack of precision and to distribute the fall over the dangerous area even more uniformly than theory requires. The risk in occupying the field of fire is enormously increased; and even one such 16-mortar battery, skilfully served, should go far to deter a ship from anchoring anywhere within a range of from one to five miles with a view to the bombardment of a distant city.

**Economy of Mortars.**—The cost of mortars themselves is small compared with that of guns, for they are not so much exposed to excessive powder-pressures, and may perhaps be made even of cast iron if any trustworthy mode of loading at the breech can be adapted to that material. The additional weight needful with cast iron is perhaps no disadvantage in view of the difficulty of controlling recoil; but experience at Sandy Hook indicates that breech-loading is essential to give the regular and uniform velocity of rotation upon which precision of fire depends. With muzzle-loading in so short a bore, the expanding sabot acts irregularly, and the shells are liable to tumble or to take up a wabbling flight inconsistent with uniformity of range.

The cost of a mortar-battery is trifling as compared with that for guns. Including masonry magazines for a large supply of ammunition, bomb proofs of ample size for all the needs of the garrison, and engine and boiler-rooms for supplying power for serving the pieces, the cost would range from $2 000 to $6 000 per mortar, according to the local requirements of the site. I constructed at Willets Point in 1872 a 16-mortar battery embodying the above principles, at a total cost of $25 000.

But, it may be asked, why do not mortar-batteries, with all these merits, solve the problem of a modern coast armament, and thus render unnecessary the heavy expense of high-power steel guns and armored defences in which to mount them? Two defects inherent in vertical fire furnish the answer. It can only be used with effect upon vessels under way by the aid of a theoretically perfect system of position-finding; and from lack of energy in the projectiles it is little to be dreaded at short ranges. If the enemy can approach much within a mile, no destructive blow will be struck by a descending projectile fired even at 75° elevation. The best field for horizontal fire is thus the worst for mortars; they are allies but not substitutes.

## SUBMARINE MINES.

**General Conditions.** — The following are the general conditions which military engineers consider should be fulfilled by this system of channel obstructions:

*First.* The mines must be so arranged as to admit of the safe passage of our own vessels, while they can instantly be rendered dangerous to the enemy. This condition can only be fulfilled by employing electricity as the igniting agent. When there are several parallel channels, it may be admissible to

close some of them by self-acting mines; but such instances are exceptional, not the rule.

*Second.* Mines which can be exploded only by judgment, at the will of an operator on shore, have a very limited application. In the night, or a fog, or the smoke of a bombardment, or when several vessels are approaching abreast, or when the water is deep, or when the channel is wide, the chances of failure are very great. Indeed, the destructive range of practicable charges is so limited that, if the ship be constructed with double cellular bottom and water-proof compartments, judgment-firing has become nearly obsolete for any but very narrow channels. In general, therefore, the system must be automatic, the explosion occurring in consequence of the touch of the enemy; but it should also admit of judgment-firing by groups when desired.

To meet the contingency of interference by our own vessels, or the use of defensive outriggers by the enemy, provision must be made to delay the explosion after contact, if desired, until the order to fire can be given by the officer directing the defence. Since the apparatus must be operated in a casemate, from which no view of the channel can be had, this condition implies not only an arrangement of the apparatus by which a contact may report itself without firing the mines, but also a telegraphic communication with the ramparts. As a vessel moving at a high rate of speed will remain only a few seconds within dangerous range of a mine, a perfect code system is essential.

*Third.* The mines should be so disposed as to cover a large area of the channel. It is not enough to oppose a narrow belt of danger. The waters well to the front of the forts, under their close fire, and far to the rear, must be dreaded by the enemy.

*Fourth.* Since the mines may remain in position for long periods, the system must provide electrical tests, by which the condition of every part may often be verified in detail; and it must also be arranged to admit of repairs in case of need.

*Fifth.* All of the mechanical arrangements of the mine must be simple, enduring, and strong enough to resist shocks from friendly vessels and from the explosion of neighboring mines; and special precautions against twisting and undue depression by currents must be taken for all floating parts.

*Sixth.* Every practicable auxiliary expedient should be adopted. Movable torpedoes controlled from the shore, and the electric light, are obvious aids. In addition, the operating apparatus should be arranged to provide for the automatic firing of flanking guns in case of any disturbance of the system by the enemy under cover of night or fog. The electric cable should have sufficient weight to sink into the mud in favorable localities, thus increasing the difficulty of boat-grappling; strong hemp cables, weighted at short intervals, should be anchored in the mine field with the same object in view; and, lastly, dummy mines and false buoys should not be neglected.

As to the disposition of the mines in the channel engineers are not entirely agreed. Some limit them to two or three well-defined lines which cannot be traversed because the least distance between contiguous mines is less than the width of a ship of war. One fatal objection to this mode of planting is, in my judgment, that, with the practical difficulties to be encountered in most places, it is impossible to plant mines so near together without bringing some of them accidentally, in so close proximity that one explosion will endanger the neighboring mines. A still stronger objection to the plan is that it greatly favors the

kind of attack we have most to dread, that by countermines. Such minute refinements are out of place under water. If it is known or believed that the channel for three or four miles is thickly studded with effective mines, the enemy will never attempt to run past until he has found some way of opening a reasonably safe passage. Nothing is so certain as chance in such cases; and the knowledge that the individual mines are none of them nearer than even a couple of hundred feet of each other will not induce a wise man to try to run the gauntlet unless he can see them. In other words, I believe that it is the total number of the mines rather than great exactness of location which will best bar the passage. But, on the other hand, it would be almost impossible to thoroughly defend a channel without having some regular system of working. The cables would become hopelessly entangled, so that no repairs of the system would be possible, if each mine were planted independently of the others. Hence the use of the multiple (seven-cored) cables leading to separate groups becomes a necessity; and these groups can be planted more readily by assigning definite positions to the mines. Moreover, by placing three mines on each separate cable, each of them will explode singly if struck; while all three will be exploded simultaneously when fired at the will of the operator on shore. The efficiency of the whole system will be increased by this mode of planting, and the use of the enormous charges favored in France and in some other countries will be avoided.

For these and other reasons it appears desirable to cut the field by continuous lines, with ample intervals between mines to prevent them from becoming mutually destructive when fired; and to fill the gaps between lines by single-cable mines admitting only of automatic action. Upon this system it is possible to

thoroughly obstruct a large area of channel without increasing to an extravagant extent the total number of individual mines.

There are two other mine systems which require special arrangements. The object of one is to obstruct a restricted area available for occupation in conducting a distant bombardment; this is specially easy if the water be so shallow as to permit the use of ground-mines. A few large and carefully located charges, arranged preferably for judgment-firing (so that their discovery by sweeping shall be made as difficult as possible), will reinforce mortar-firing in a very effective manner. Such mines, technically called "detached groups," will certainly be used to cover anchorages like that near Coney Island, whence a vessel, without crossing the bar, might annoy Brooklyn. The system permits the use of cable too much deteriorated for automatic firing, and may have an extended application under certain contingencies.

The other special system is employed when we can afford to sacrifice one or more channels because we have the use of a better one defended by electrical mines. Such an obstruction would be made by the use of self-acting mines, dangerous alike to all comers. The only remark I have to make in respect to this class is that no pattern which fails to fulfil three conditions should be received with favor. These conditions are, (1) that no safety arrangement which requires the act of the planting party to remove is admissible; (2) that some arrangement to cause the immediate explosion of the charge if the mine goes adrift is essential; and (3) that every possible means should be taken to make the removal difficult. There appears to be a difference of opinion among engineers as to this last point; but I think it arises from overlooking the fact that it is impossible to easily remove ourselves what an enemy informed as to the mechanism cannot also

readily clear away. No compromise in such a case is possible. If we want efficiency we must pay the price by incurring difficulty in opening the channel when the need for the obstructions has passed.

This same class of self-acting mines may sometimes find useful employment in repairing injuries done to a regular system of electrical mines by countermining. To be of much use the passage opened by the enemy must be well marked and buoyed. A few self-acting mines dropped in it by night would prove extremely dangerous; and such mines are very easily handled and rapidly planted. All that is necessary to render the expedient easy of application is to adapt the special parts of the self-acting mechanism to the ordinary electrical mine, so that when desired it may be planted to act in either capacity.

To operate electrical submarine mines successfully, large voltaic batteries and delicate apparatus of various kinds are indispensable. To expose this material to boat attacks, or even to distant bombardment, would be inadmissible, for even a slight injury here might open the channel to the enemy. The operating apparatus is the most vulnerable part of the system; hence the accepted principle that mines must be served from strong land fortifications. A sunken gallery leads from the water edge at lowest tide, under the foundations of the fort, to a vertical shaft opening into a bomb-proof casemate which contains the apparatus. This apparatus is connected with the ramparts by telegraph, so that the engineer is fully informed as to what is electrically reported by the mines, and at the same time is able to see what the enemy is doing and to take measures accordingly.

**Attacks by Daylight.**—Where the defence is believed to be weak, ships, by the use of outrigger frames or wire-rope crinoline, may try to explode at

a safe distance such mines as may chance to be encountered. But with electrical mines the engineer will simply delay the explosion until the torpedo has passed under her bottom; or, if such devices should ever be made really practicable, he will plant his circuit-closer buoys a little in rear of his mines, and thus cause the explosion to occur precisely where he wants it. Finally, the crinoline being certainly swept away by the first explosion, the ship will be left, encumbered by the wreck, among other mines equally dangerous.

Should divers be sent forward to destroy the system, so soon as their work is revealed by the electrical indications a mine fired in the vicinity will at once put an end to their labors.

If old hulks, steered by electricity, be sent forward to explode the mines in the channel, or if rafts provided with grapnels be allowed to drift in with the tide, the engineer will switch off his batteries; and, although injury may result, a terrible uncertainty will be left to the enemy as to how many perfect mines may still be waiting to receive him.

Remembering that a cleared and buoyed passage is a *sine qua non* for the fleet, and that by daylight the guns of the fort will sweep the mined zone with a murderous fire, the uncertainty of any unsystematic attack is apparent. The only successful method of attacking land mines has been shown, by the experience of centuries, to be by countermines, and I believe that future wars will teach the same lesson for sea mines.

Steam-launches, controlled by electricity or otherwise, or small, heavily armored vessels made for the purpose, will move up to the supposed outer limit of danger; will plant from one to four 500-pound countermines; will back off, and by exploding them by electricity will destroy any mines in the immedi-

ate vicinity. The vessel will then steam forward into the vortices and plant one or more buoys. By repeating this operation it is clear that a safe channel may be opened and plainly marked; and that, finally, the fleet will be free to move rapidly through it past the guns.

These countermining operations, however, will be neither expeditious nor safe. The vessel will necessarily indicate her successive positions of rest, and the mortars and guns will prepare volleys for her reception at points where her exact locus is known. Movable torpedoes under control from the shore will assail her below the armor belt, however massive that may be. By night new mines will be dropped in her buoyed channel. In fine, the delays, disasters, and murderous struggles familiar in land-mining will in future wars find their counterparts on the sea.

**Attacks by Night or in Fogs.**—Under such conditions the firing of the guns and the operating of the mines cannot be so intelligently directed by the defence; but, on the other hand, the enemy can derive little information as to the details of the damage inflicted, unless he sends boats forward to work systematic mischief and to drop buoys accordingly. How to defend the mines against boat attacks conducted when shrouded from view becomes, therefore, an important engineering problem. The best of all assistance can be rendered by a flotilla of naval picket and torpedo-boats; but when they cannot be had, four useful auxiliaries may be employed—fouling-lines, automatic action of the guns, the electric light, and, last but not least, movable torpedoes under control from the shore. I shall say a few words as to how engineers propose to make use of each of these auxiliaries.

Nets to foul propellers are too well known for discussion. As a defence against attempts to grapple

the cables, whether by drifting rafts, or by the somewhat fanciful scheme of mortar-boats throwing grapnels, or by ordinary steam-launches or small boats, a few hawsers anchored in front of and among the mines will certainly be found useful. They should be attached to the heavy anchors or blocks of stone used to hold them in position, by short lashings, to prevent them from being drawn under the mud. Multiple cables for mines soon bury themselves by their own weight in the soft bottom of many of our harbors ; and, as a harmless hawser can only be detected by raising it, the enemy must either lose time in so doing, or, if use be made of explosive grapnels, he will be led to over-estimate the damage he is inflicting.

Main lines of mines should be so arranged as to be swept throughout their length by the fire of flanking guns. These guns, charged with canister, grape, or shrapnel, according to the range, should be trained by daylight to sweep their respective fields. Cables extended to the mining casemate place these guns, in groups, in connection with the electrical system, and any injuries to mines or cables will at once draw the fire of the guns pointed to annoy the boat which has done the mischief. The artillery officers are thus informed that parties are grappling and that their position lies in a certain direction. Knowing the latter, they will keep up such a fire as will stop or, at any rate, greatly harass the boats.

As to the utility of the electric light in channel defence, I think a better idea can be formed after it has been more fully tried in war. Before firing begins it will doubtless be very useful, but so soon as the air becomes obscured by smoke from the guns, or from smoke-balls burned for the purpose, experience leads me to doubt its value. It will be most useful in clear, dark nights ; in bright moonlight nights,

and especially in fogs, I think little dependence will be placed on its assistance by engineers.

The usual dispositions of the apparatus in a fortress are to place the engines and dynamo in a bomb-proof casemate, and to throw the beam from a station near the water-level, either directly or by reflectors, according to circumstances. Stations should be duplicated and be placed near the flanks of the position, to avoid smoke driven by the wind.

In the absence of an effective fire of artillery, and particularly when special vessels shall have been constructed for countermining, movable torpedoes controlled from the shore can be made to play an important part. Unless the currents are strong there is no urgent need of very high speed, say above 10 miles per hour. The most valuable points, from an engineer standpoint, are: (1) Invulnerability to fire, whether of machine guns, of rapid-firing guns, or of cannon throwing grape and canister. (2) Capacity to carry three or four hundred pounds of the explosive. (3) A range of at least two miles. (4) The power of diving under any simple boom protection, such as a ship could easily improvise from her spare stores. The ordinary service conditions, such as being under perfect control, presenting a small target, etc., etc., of course are essential. All these conditions can be fulfilled in practice, and I entertain no doubt that such boats will form an important but subordinate element in every perfect system of coast defence.

Much has been said of late as to the probability of torpedoes of this class being superseded by large charges of dynamite or other high explosives, thrown by pneumatic mortars (usually called guns), and provided with fuses which cause explosion either at impact or when submerged. In advance of official reports it would be premature to form any decided

opinion on the subject; but it is certain that one fatal objection would lie to this proposed application —we could hardly fail to damage our mines, and thus perform for the enemy work which it is the part of wisdom to force him to undertake himself. The controllable torpedo causes one explosion under the bottom of the counterminer, and this is far preferable to many explosions well distributed by ourselves among the mines upon which our successful defence depends.

**Attempted Passage by Force.**—After the enemy imagines that he has opened a clear channel through the mined field he will attempt to force a passage. The following preparations will be naturally made: The position of the commanding officer, of the chief of artillery, and of the engineer in charge of the mines will be at some selected place where smoke from the guns will not be likely to annoy them; where the instruments, so far as possible, can be kept under cover; and where a good view can be had of the mined zone. Two electric cables terminate at this station. One extends to the mining casemate for telegraphic communication; the second leads to the other extremity of a base line, for triangulations to fix exactly the position of the enemy —unless, indeed, some superior method of position-finding be used.

The map of the channel being always at hand, with the locus and condition of the mines and the successive positions of the enemy as he approaches laid down upon it, the commanding officer will always understand the state of affairs; and the engineer can direct the service of his mines, and the artillery officer that of his guns, under every possible advantage.

# FIFTH LECTURE.

## SEA-COAST FORTRESSES.

Historical résumé of Coast Defence in America—Resistance to projectiles; armor; masonry; earth—Approximate formulæ—Fortification of the site selected—Naval co-operation.

HAVING, in the previous lectures of this course, passed in review the general principles of the art of war applicable to sea-coast defence, the probable nature of the naval attacks which will be brought against the works, the financial aspects of the question, the selection of suitable positions for the batteries, mines, etc., and the character of the several elements composing them, it remains to consider how the latter are to be combined at any site to constitute a sea-coast fortress.

If our coasts were entirely devoid of defensive works the problem would be different from that now presented. To take a broad view of the subject it is needful to appreciate what the existing works were designed to accomplish, to understand their construction in some detail, and to consider what use can be made of them under the changed conditions of the problem now presented. I shall, therefore, first ask your attention to a brief outline of the development of sea-coast fortification in this country.

### HISTORICAL RÉSUMÉ OF COAST DEFENCE IN AMERICA.

Previous to the Revolution our seaport towns were villages, and naval establishments and military

depots were unknown. The harbors of Boston, New York, Philadelphia, Charleston, etc., had been protected by a few insignificant earthen forts; but at the outbreak of war the sparse population and long coast line enabled the mother-country to use the ocean for her base, and to operate where she wished until the French appeared on the scene. A small work of sand and palmetto-logs in Charleston harbor, however, under the command of Colonel Moultrie, decisively repulsed the attack of a British fleet of two frigates and six sloops of war (30 guns against 270) in 1776, and thus taught our people the value of fortifications. The battle lasted upward of ten hours, and its result gave a local respite from the calamities of war for two and a half years.

Shortly after peace had been declared Washington urged the necessity of defending the coast, and the French troubles drew popular attention to the subject. Fort Columbus, Castle Williams, and Castle Clinton (now known as Castle Garden) were built in New York harbor; and in nearly all of our chief ports batteries made their appearance, but they were of so defective design, and so weak and perishable in material, as to have no permanent value. This (known among engineers as our second system of defence) did, however, some service in the war of 1812. New York and Boston were blockaded, not occupied; but the shores of Long Island Sound and Chesapeake Bay were ravaged, and the whole New England coast was kept in terror by raiding expeditions. This bitter experience bore fruit, and no sooner had the war ended than the defence of the Atlantic seaboard was seriously taken in hand.

In 1816 a Board of Engineers was constituted to examine the sea-coast and to prepare plans for defensive works, subject to the revision of the Chief of Engineers and to the sanction of the Secretary of War.

This important Board, which at the outset consisted of General Simon Bernard, Colonel William McRee, and Lieutenant-Colonel J. G. Totten, may justly be said to have originated the first permanent system of coast defence on this continent. Indeed, at that date European treatises on fortifications scarcely touched on this branch of the subject, so little was science supposed to be concerned in the throwing-up of batteries to contend with ships.

Perhaps no better idea of the problem before the Board of Engineers can be given than by quoting the language of a contemporary writer, a British officer who had taken part in the expedition against Baltimore. He wrote:

"America must be assaulted only on her coasts. Her harbors destroyed, her shipping burned, and her seaport towns laid waste, are the only evils she has reason to dread. . . .

"To the plan proposed, of making desert the whole line of coast, it may be objected that by so doing we should distress individuals and not the government. But they who offer this objection forget the nature both of the people whose cause they plead and of the government under which they live.

"In a democratical government the voice of the people must at all times prevail. The members of the House of Representatives are the very persons who, from such proceedings, would suffer most severely, and we all know how far private suffering goes to influence a man's public opinions. . . .

"By compelling the constituents to experience the real hardships and miseries of warfare you will compel the representatives to a vote of peace. . . . Burn their houses, plunder their property, block up their harbors, and destroy their shipping in a few places, and before you have time to proceed to the rest you will be stopped by entreaties for peace."

The Board of Engineers, in a report dated in 1826, gave a general résumé of the principles which had guided their labors, and of the progress which had already been made. I shall quote two sentences which specially relate to the subject now under consideration:

"The means of defence for the seaboard of the United States, constituting a system, may be classed as follows: First, a navy; second, fortifications; third, interior communications by land and water; and, fourth, a regular army and well-organized militia. . . ."

"Fortifications must close all important harbors against an enemy, and secure them to our military and commercial marine; second, must deprive an enemy of all strong positions where, protected by naval superiority, he might fix permanent quarters in our territory, maintain himself during the war, and keep the whole frontier in perpetual alarm; third, must cover the great cities from attack; fourth, must prevent as far as practicable the great avenues of interior navigation from being blockaded at their entrances to the ocean; fifth, must cover the coastwise and interior navigation by closing the harbors and the several inlets from the sea which intersect the lines of communication, and thereby further aid the navy in protecting the navigation of the country; and, sixth, must protect the great naval establishments."

We will now consider briefly the character of the individual works constructed in inaugurating this comprehensive system.

Ever since the general introduction of gunpowder into warfare, the rule has been recognized that no masonry must be exposed to the fire of *land* guns; but this rule was not deemed applicable when *ships*, themselves much more vulnerable than stone walls,

carried the guns. Moreover, the distinguishing characteristic of the line-of-battle ship of that day was her enormous concentration of fire. To reply with equal chances of success, *many* land guns were demanded; and space was lacking for them at most sites, unless advantage were taken of the facilities to pile tier above tier afforded by a masonry scarp.

The use of the casemate in flank defence may be traced back to the early part of the sixteenth century; but the Marquis de Montalembert, writing near the close of the eighteenth century, had recently given the invention an extraordinary development To the needs of sea-coast fortification casemates were peculiarly well adapted, and he had presented special designs for the purpose. The forts constructed to defend the roadstead and harbor of Cherbourg in 1786 were patterned after these designs; and other Euro pean nations followed in the same track. As already stated, Colonel Williams introduced casemates into this country by the construction of Castle Williams and sister forts in 1807; and the Board of Engineers adopted them as the basis of the permanent system.

Time is lacking to trace the development of that system, and the successive improvements introduced by General Totten during the construction of the works. They were radical, especially as to the details of the embrasure; he reduced the dangerous opening from 28 square feet to about 10 square feet, and this with an increased traverse and elevation for the gun. He was also the first to introduce iron for defensive purposes into sea-coast forts. This innovation resulted from a series of experiments carried out at West Point between the years 1852 and 1855. The throats of all embrasures constructed after 1858 were reinforced by 8-inch wrought-iron plates set into the masonry; and, during the loading of the guns, the embrasure openings were closed by iron shutters two

inches thick and proof against the largest grape. There is one sentence in General Totten's report upon these experiments, dated March, 1857, which is pathetic as showing that the shadow of the great change about to occur in naval warfare, which was destined even before his death to sweep away the system of forts he had elaborated by the labor of his whole life, had made itself perceived. He wrote in 1857:

"Were it not for the vastly greater cost, the whole scarp might be faced with iron—indeed, might be made of iron only; but, until there shall be much stronger reasons than now exist, or are now anticipated, for believing that well-constructed masonry batteries may be breached by naval broadsides, the cheaper construction can be safely followed—especially as, should such a necessity ever arise, they may be externally plated with iron."

The actual construction of works upon General Totten's system covered a period of 45 years, terminating about a year before the close of the civil war. They are masonry structures, usually placed but little above the water-level, rising into one, two, or three tiers of casemates and surmounted by a tier in barbette. The scarps are built without any bonding of the masonry into the supporting piers (which would cause unequal settling on such sites as most of these works occupy). In all the later works the scarps of the water-fronts are 8 feet thick; where they are backed by the piers of the casemates the reinforcement amounts to 2½ feet; the masonry of the casemate arch, above the level of the communication arch, extends a solid support to the whole structure over 30 feet thick; immediately in front of the guns, at the "recess," there is a small space where the thickness is reduced to 5 feet. In some of the earlier works the casemate arches were sprung at the level of the barbette tier and covered four guns each, the

two of the second tier resting on a wooden floor; but all the later scarps are solidly backed against single arches. In plan these works are usually hexagonal, often truncated on the land side. The superiority of the hexagon arises from its permitting the casemate guns on adjacent fronts to be fired in parallel planes at their extreme traverse (30 degrees). This covers and prevents a dead angle at the salient between them. Where there is a barbette tier, the guns, admitting of a traverse of 60 degrees from the front in each direction, strongly reinforce the fire of the casemate guns over this naturally weak angle.

So soon as the work of fortifying the coast was resumed after the civil war a radical change of system occurred. Masonry was provisionally abandoned, and earth was substituted for every kind of cover. Under this system, which continued until appropriations ceased in 1875, many batteries were built at important positions; and they will serve a good purpose, notwithstanding the rapid progress in guns which has occurred since they were built. After 1870 these earthen batteries were constructed to receive, if desired, the pattern of the King disappearing carriage designed for the 15-inch gun.

All the sites now owned by the United States suitable for the erection of defensive works, contain specimens of the different types just described; and it is therefore a live question what shall be done with them when work is resumed. As stated in a former lecture, many of the old masonry forts, with their old armament, will be not without value for the necessary flanking of the submarine mines; and the later earthen batteries may often be modified to receive guns of the new type. But the general problem compels the consideration of a subject which I have heretofore passed over—the relative and absolute resistance opposed by different kinds of materials, such as armor, masonry, and earth, to modern projectiles.

## RESISTANCE TO PROJECTILES.

**Armor.**—The armor question is by no means the same for land fortifications as for ships. The element of weight, so important when displacement is involved, demands far less consideration when the solid earth supplies foundations. The ratio between resistance and weight has decided the matter for naval uses, steel or compound armor being now universally adopted. The decision for forts is still an open one. Heretofore Engineers have confined themselves either to wrought iron or to the Gruson chilled cast iron, no steel or compound armor having yet been used or strongly advocated for use in coastwise works.

Wrought-iron armor localizes the injury better than steel or compound armor, and thus saves the general structure; the Gruson metal breaks up and deflects the projectile, and absorbs the remaining energy by so large a mass that its strength to receive further shocks is often not seriously impaired. Captain Bixby, Corps of Engineers, in a recent official report upon duties which had been assigned to him in Europe, sums up the case in what I regard as a fair statement, except perhaps that he lays hardly enough stress upon the fact that chilled cast iron does not admit of subsequent thickening, while the other kinds may readily be reinforced if necessary. He states:

"At the present date heavy armor (from 12 to 40 inches thick) is very expensive, its cost, firmly mounted in place, being approximately as follows: wrought iron, from \$200 to \$350 per ton; steel-faced wrought iron or surface-hardened steel, from \$400 to \$600 per ton; chilled cast iron, from \$150 to \$200 per ton. . . .

"Taking into consideration the cost of bolts, bolt-holes, and other means of assemblage, and the

cost of fitting and setting up the armor, the same amount of money will, roughly speaking, furnish a steel-faced wrought-iron or surface-hardened steel armor of 20 inches thickness, a wrought-iron armor of 40 inches thickness, or a chilled cast-iron armor of 60 inches thickness. Roughly speaking, the steel-faced wrought iron or surface-hardened steel is least heavy, the strongest in proportion to its thickness; the wrought iron is easiest to make, easier worked, easier added to, best against racking shots, localizes best the effect of a shot, can best be penetrated and even perforated without being actually destroyed, and can best have the amount of penetration calculated in advance; the chilled cast iron is easiest and quickest made, can be given any shape, requires the least working, is easiest and quickest placed in position, is never penetrated, always shivers in pieces the striking projectiles, generalizes best the effect of a striking projectile, provides the greatest weight or mass to receive the total living force of the striking projectile, has no bolts to be knocked off on its interior, and sends off the fewest splinters on its interior. The steel has undoubtedly the advantage around the edge of embrasures, and wherever thickness or weight is undesirable or inadmissible, also wherever it can be backed by a great thickness of less expensive masonry; the chilled cast iron has undoubtedly the advantage . . . wherever weight or mass is an advantage."

In the matter of bolts, wrought-iron armor requires one to each 10 or 12 square feet of surface; compound or steel armor requires one to each four square feet of surface; chilled cast iron dispenses with bolts entirely.

Wrought-iron, steel, and compound or steel-faced armor are so familiar to naval officers that no time will be given to their further discussion. Gruson chilled

cast iron, being inapplicable to floating structures, is probably less studied, and the following short extracts from a publication by Julius von Schutz, Engineer of Gruson's Works, which has just left the press, may perhaps be not uninteresting:

"The Gruson chilled cast iron is a mixture of different blends of pig-iron, cast in chill, to which it owes its hardness.

"In accordance with the two chief qualities which he sought to obtain, Gruson chose two sorts of pig-iron for his principal materials, each of which possessed one of the desired qualities—a highly carbonized steel-hard, white iron, and a soft gray iron.

"Although it appeared impossible, by the mere mixture of the two metals, to combine hardness and toughness in the same stratum of iron, another way of solving the problem, to produce a hard surface on a soft, elastic interior, seemed less difficult if it were possible to combine the two different materials together with such a gradual change of their respective properties that no marked line of separation should occur; and this is the problem which Gruson, after years of effort, succeeded in reaching in such a manner that even at the present day his chilled cast iron possesses a superiority over that of other makers.

"Gruson attained his object by a seemingly simple procedure. By the use of iron forms, or moulds for casting, he prevented, by a rapid cooling of the surface, the always existing tendency in a fluid casting for the carbon to separate off in scales of graphite.

"It would be foreign to the scope of this compilation to specify the details of the manufacture of the chilled cast iron, and we will only describe the peculiar structure which characterizes the broken section of a piece of the Gruson chilled cast iron. The exterior layer is of a fine fibrous character, which passes, without visible lines of separation, into the granular struc-

ture of the so-called mottled iron, which in turn gradually assumes the character and fine crystalline structure of the gray soft iron. This is the great difference which distinguishes Gruson chilled cast iron from that of other manufacturers, in whose iron the line of separation of the layers is always more or less distinctly marked, and the edge between the hard and soft metal visibly seen. . . .

"To his plates he gave a curved form, which in vertical section approaches that of a quadrant of an ellipse. Such a surface, by its hardness, deflected the shot striking it, and besides it possessed this advantage, that, by reason of their arched form, the plates supported one another and retained their position by their weight, without the necessity of securing them by bolts."

I have already shown that it would be unwise to devote the first funds granted by Congress for coast defence to the purchase of armor of any kind; it is certain that whatever is purchased must be manufactured in this country; the facilities for working heavy masses here are steadily increasing; the struggle between the different kinds of armor has not ceased in Europe; and when the time comes for purchasing, the choice may be affected by conditions materially different from those now existing. For these reasons the Corps of Engineers has never committed itself to a definite choice. We know that wrought-iron armor 8 feet wide, 10 inches thick, and weighing from 10 to 12 tons can now be rolled in this country; that larger plates could soon be fabricated were there any demand for them; that probably the same will soon be true for steel, and that, if sufficient inducements were offered, works for making the Gruson chilled cast iron would be quickly established. In my judgment, therefore, it is the part of wisdom for us in this matter to say with the Russians: "I sit upon the bank and there I await the wind."

**Masonry.**—Very few experiments have been made to determine the penetration of modern ordnance in masonry.

In 1877 an unfilled Palliser shell was fired from a 12.5-inch 38-ton gun at a mass of masonry at Shoeburyness. The projectile weighed 800 pounds, its striking velocity was 1 405 feet, and its energy 10 080 foot-tons. The masonry was an old experimental casemate, somewhat shaken by previous firing; it was 16 feet by 12 feet by 16 feet high. The shell, after passing through 5.5 feet of granite and 5.5 feet of brick and Portland cement concrete, was found on the floor of the casemate. The wall was completely wrecked.

In 1881 the cast-iron 100-ton gun made in Italy was fired at a steep rock face. The projectile, weighing 2 200 pounds and striking with a velocity of 1 456 feet, had an energy of about 32 000 foot-tons. The penetration was over 20 feet.

A concrete butt at Dungeness was fired at with smaller projectiles in 1881. The concrete had been made of rounded shingle about two years before, and was not so solid as if the material had been more angular. The following were the maximum penetrations, the energies being respectively 5 738, 1 989, and 1 555 foot-tons:

A 10-inch M. L. rifle of 18 tons: Palliser shell, 17 feet; common shell, 13.8 feet.

A 6-inch B. L. rifle of 80 cwt.: Palliser shell, 12.6 feet; common shell, 10.8 feet.

A 6.6-inch M. L. rifle of 70 cwt.: Palliser shell, 8.2 feet; common shell, 8.4 feet.

In 1883 a muzzle-loading 80-ton gun was fired at a masonry target at Shoeburyness built for the purpose. The projectile was chilled cast iron, 1 700 pounds in weight. The striking velocity was 1 580 feet per second, giving an energy of about 30 000 foot-tons. There are some discrepancies in different

statements respecting the details of this experiment. I was informed on the spot a few days after the firing that the shot passed through 9 feet of granite, 6 feet of good Portland cement concrete, and then encountered a brick wall 5 feet thick, the whole forming one solid wall, backed by buttresses of concrete 20 feet thick. The brick wall deflected the shot from its course, and it curved to the right and finally to the front, after passing over a total distance of about 25 feet. The shot broke up.

Another similar shot was fired at a mass of Portland cement concrete about 40 feet thick, made about 9 months before. The penetration was 32 feet (Captain Lewis, R.E., says 34 feet) on a straight course; the mass was also badly cracked.

Another similar shot was fired at a compound plate of steel-faced wrought iron, 12 inches thick, secured without any elastic backing to a masonry mass 20 feet thick, like that first described. The shot bulged and just penetrated the plate, so that its point appeared at the back, and the injury to the masonry was insignificant.

Another similar shot was fired at a wrought-iron sandwich target backed in the same manner. The target consisted of two 8-inch plates, separated and backed by 5 inches of wood. The shot traversed the shield and granite, resting at the concrete just behind it (penetration, 16 inches of iron, 10 inches of wood, and 9 feet of masonry).

In 1884 the 12-inch 43-ton gun was fired at the same target at Shoeburyness, which had been repaired for the purpose. Captain Lewis, R.E., states that it now consisted of 14 feet of granite and Portland stone, 2 feet of Portland cement concrete, and 6 feet of brick. The shot weighed 715 pounds, its striking velocity was 1 804 feet per second, and its energy 16 300 foot-tons. The penetration was 11.3 feet, and the granite was much shattered and displaced.

In firing at the concrete butt with this gun, the striking velocity was reduced to 1 524 feet per second, giving an energy of 11 620 foot-tons. The penetration was 24 feet, and a large mass 2 feet thick flaked off from the front.

The two 8 inch wrought-iron plates used as a facing, attacked by the same gun, reduced the penetration in the granite to 5.9 feet.

A mass of concrete 17 feet thick was faced by three 1-inch plates of wrought iron and backed by the granite wall. The result with the 43-ton gun was unsatisfactory, the concrete disintegrating; but General Inglis, R.E., states that the latter was not properly set.

Captain Lewis, R.E., gives the following as the results derived from the firing at the bombardment of Alexandria: "The maximum penetration of blind shell, 9-inch or 10-inch, into the soft rubble scarp of Fort Adda, was from 8 to 9 feet. A 9-inch Palliser burst with 4 feet penetration. A 16-inch common shell burst with 8 feet 6 inches penetration, and made a crater about 10 feet in diameter at the face of the wall. This was one of the best results obtained. The shell struck near the base of the wall. Range about 1 500 yards.

"At Fort Pharos the 10-inch shell, common and Palliser, penetrated the 8-foot rubble walls of the casemates and burst inside."

Comparing these results with those of former firing with less powerful guns, and allowing for the reduced effect of the ranges likely to be used in war, it appears that not less than 30 feet of good granite masonry, or 40 feet of good concrete masonry, is admissible in sea-coast forts where it is to be exposed to direct fire, and that even these thicknesses are not sufficiently great to resist a prolonged bombardment. English engineers now protect their magazines with

40 feet of masonry, but an increased thickness is anticipated.

**Resistance of Earth.**—The resistance of earth to penetration of modern ordnance is so variable, not only from difference of consistency but also from the tendency of the projectile to change direction and pass out at the top of the parapet, that it is not easy to frame a rule for suitable thickness. Clay opposes a *local* resistance like wrought iron; sand seems to wedge in front and thus resists as would a cone pressed at the vertex. This difference is marked and characteristic, and preference should therefore always be given to sand where it can be obtained at reasonable expense. The tendency to curve upward, always present, appears to increase with the range—possibly because the velocity of fall continues at the base after the point is engaged. However this may be, the fact occasioned much surprise at the bombardment of Alexandria, where no projectile, even those of the 80-ton gun, penetrated the sand parapet to a greater depth than 20 feet before coming out at the top.

Firing at Fort Monroe in 1866-67 with a M. L. 12-inch rifled gun, with projectiles varying from 500 to 600 pounds in weight, and velocities ranging from 1 100 to 1 300 feet per second, indicated that penetrations should not be estimated at less than 20 feet.

The Italian 100-ton gun (cast iron) was fired at a sand parapet in 1880-1, the projectile weighing 2 200 pounds, the striking velocity being 1 453 feet, and the energy being 32 000 foot-tons. The penetration in five shots varied between 39 and 47 feet. One of their 10-inch guns at a range of 1 100 yards gave a penetration of 24 feet into earth or 20 feet into sand.

At Woolwich, in 1880, the 12-inch M. L. rifled gun gave a maximum penetration of 55 feet in sand. Older experiments at Shoeburyness, with a butt of

stiff marsh clay, gave as a mean penetration of 23 shots with a 13.3-inch rifled gun, 36.5 feet, the maximum being 50 feet; and as a mean penetration of 43 shots with a 9.2-inch rifled gun, 32 feet, the maximum being 40 feet.

The rule given by Captain Lewis, R.E., in 1882, as the result of English trials with siege artillery of the present type, is that the extreme penetration of earth in feet is about four times the calibre in inches.

In the Lydd experiments of 1885 two shots were fired with a 9.2-inch B. L. gun, at a range of 1 200 yards, against a clay parapet 30 feet thick with an exterior slope of 45 degrees. The first shot penetrated 13 feet into the parapet; the second went through, lowering the interior crest 3.5 feet. About 61.9 cubic yards were removed. No such results were obtained with sand, or with a loam consisting of two parts sand and one part clay.

The U. S. Board of Engineers, making allowance for probable increased calibres and for craters which may be expected in action, have adopted 70 feet between crests as the proper thickness to be given to sand parapets, although, in view of the facts above stated, the probability of penetration with a less thickness would not appear to be sufficiently great to require all old parapets to be increased to this standard.

### APPROXIMATE FORMULÆ.

When planning and studying sea-coast fortresses a few rules, in a form to be easily remembered, are convenient to assist in roughly estimating the probable effect of firing.

Such are:

**For Weight of Projectiles.**—The cube of the radius in inches gives the weight in pounds of the solid spherical projectile. Modern armor-piercing

projectiles usually range from 3.3 to 4 times this weight. Another form of this rule (corresponding to a multiplier of 4) is to take half the cube of the calibre of the gun in inches for the weight in pounds.

**For Velocity of Projectiles of High-Power Guns.**—A charge of one-fourth of the weight of the projectile will give a velocity of about 1 500 or 1 600 feet per second; and a charge of one-half that weight, a velocity of about 2 000 or 2 100 feet per second. These are muzzle velocities; to estimate striking velocities up to a range of about 6 000 yards subtract from them one-tenth of the range in yards; for longer ranges the loss is less rapid.

**For Energy in Foot-Tons.**—Take seven-millionths of the product of the square of the velocity in feet by the weight of the projectile in pounds.

**For Penetration of Wrought-Iron Plates.**—Under favorable service conditions, the thickness in inches of wrought-iron armor pierced by a suitable projectile, may be estimated, with about as much precision as the subject admits, by taking one-thousandth of the product of the calibre in inches by the velocity of the projectile in feet per second. This rule, suggested by Captain Orde Browne, R.A., depends for its accuracy upon the constancy of the ratio between the weight of the spherical shot and of the elongated projectile of the same calibre. It is not far from true in ordinary practice with armor-piercing projectiles. Common shells can be put through wrought-iron plates about half a calibre thick.

**For Limit of Resistance of Steel-Faced and Steel Armor.**—The compound plates and steel plates now manufactured must be disrupted rather than perforated; and their extreme resistance (not materially different for these two kinds of armor) is usually estimated in terms of the thickness of wrought iron which opposes an equivalent resistance

to perforation. This has been shown by many trials to vary between one-quarter and one-half greater thickness, the latest accepted value being one-third greater thickness—*i.e.*, a 9 inch steel or compound plate is equivalent to a 12-inch wrought-iron plate, since a projectile which will perforate the latter will usually disrupt the former. It must not be forgotten, however, that much depends upon the *projectile itself.* When the latter is broken up by the shock its work on the plate is greatly and irregularly reduced; and until quite recently this rupture appeared to be unavoidable with very heavy armor. Within a year, however, a 16.5-inch St. Chamond steel battering shell, with a striking velocity of only 1 410 feet per second and an energy of only about 24 000 foot-tons, traversed, entire, a 19.7-inch Creusot steel armor-plate, and fell 400 metres beyond it, upset one-quarter of an inch! Also 12-inch Holtzer projectiles have penetrated 16-inch compound plates practically uninjured.

There is little utility in attempting to construct a formula to predict the effect of the impact of so diverse projectiles as have been used in firing at steel and compound armor, but I find the results of many of the experiments to be fairly represented by the following rule: A steel or compound plate with ordinary backing rarely fails to yield to a projectile having an energy in foot-tons represented by sixty times the square of its thickness in inches.

**For Resistance of Chilled Cast Iron.**—No formula for the resistance of this kind of armor has been generally accepted. Gruson's rule for the maximum thickness in inches to be given to his plates is the product of a constant by the fourth root of the energy in foot-tons to which it is to be exposed. His constants are: For port-plates 0.29; for side-plates, 0.27; for glacis-plates with earth in front, 0.22; and

for glacis-plates with granite in front, 0.20. For inland fortifications these constants are increased ten per cent.

## FORTIFICATION OF THE SITE SELECTED.

Coast defences differ radically from ordinary fortifications, in that they are not expected to resist an attack by formal land approaches. They must be planned to resist capture by surprise or by storm, but not by regular saps. Moreover, our sea-coast fortresses of to-day will be much less exposed to boat attack than were those planned in 1816. Not only has the increase of population and the extension of railroad and telegraphic communication rendered it vastly more easy to concentrate reinforcements, but the reduction of crews in naval war-ships has lessened the force available for landing operations.

For these reasons the idea of constructing a fortress to contain all the water-bearing guns within its enceinte has long been abandoned. The ordnance is now distributed in detached batteries, each provided with minor defensive arrangements suited to the locality, while the whole position is made secure by a central keep. This is usually a small enclosed work, fortified on the principles recognized in land constructions. It should be concealed from the view of hostile shipping; should contain or flank the casemate for operating the submarine mines; and should command as many of the detached batteries as the site will permit.

Four kinds of fire are requisite to contend against a modern fleet: (1) A sufficient array of armor-piercing guns to attain the vital parts behind a belt of steel about 20 inches thick, at ranges of 1 500 to 2 000 yards. (2) Guns throwing large common shells

to destroy the upper works, which in the more recent types include an area so much larger than the armored belt that this kind of fire is the most effective at ranges exceeding 2 000 yards. High-power guns of moderate calibres, or even a less efficient armament, will serve this purpose. Rapidity of fire, calling for many guns, is needful. Here the use of high explosives in shells, which (if not now) is certain to be soon available, will play its most important part. (3) Vertical fire from heavy mortars, to attack the lightly armored decks at ranges exceeding 1 500 yards; and (4) Light guns, including machine and rapid-firing guns as well as the old types throwing canister, shrapnel, and shells, to flank the submarine mines, repel boat attacks, and contend with the torpedo-boat armament of the ships if they can approach sufficiently near to bring it into play to annoy the cannoniers in serving our high-power guns. At long ranges machine-gun fire is useless because its effect cannot be noted.

No precise rules can be laid down for fixing the relative proportions of these different types in a modern armament; the engineer must study his special problem and be governed by local conditions. In little else can his professional skill be better displayed. The principles which should determine the number of battering guns and their largest calibres, have already been considered.

In planning the works the chief objects are: to dispose separate gun batteries in such a manner as to cover the field of fire thoroughly without leaving dead angles, and to permit effective concentration upon the more important channels; to place the mortar batteries where they will be concealed as much as possible from view, and where their smoke shall not interfere with the guns; to locate the submarine mining casemates where they will be secure against

bombardment; and, finally, to make the needful provisions against surprise by boat parties.

The separate batteries will be much more scattered than formerly—partly to avoid mutual interference by smoke, which, being dependent on the amount of powder burned, will, unless provided against, be a more serious annoyance than ever before; and partly to prevent the enemy from obtaining that concentration of fire which his reduced number of guns will render more than ever desirable. The new phases of modern warfare have thus introduced a dispersed order in sea-coast batteries as well as in the shock of armies in the field.

Machine guns will play an important part in defending such a system of works against assault. They concentrate within a small space the fire of whole regiments under the old system; they may be withdrawn from view, and be made safe from capture, at small expense; and, lastly, they avoid the necessity of providing bomb-proof quarters for a large garrison. Still a reserve, in moderate numbers, is a necessity; and provision for cover during bombardment, and a strong keep to serve as a rallying point in case of a formidable attack, will form a part of every important sea-coast fortress of to-day. Trous de loups, wire entanglements, ordinary arrangements for ditch defence, etc., will of course be provided according to local needs, but works of this character will be largely left to be placed by the garrison so soon as war is declared.

Before a fortress can be planned some definite estimate must be formed as to the size of its war garrison. The rule abroad is to determine the number of cannoniers needful to serve all the guns likely to be in action at the same time, and the number of the guards; to allow three reliefs for these duties, and to the total thus found add the number of men probably to be detailed on special duties.

Such a garrison would be much larger than would be available in this country without reinforcements of volunteers; and in general it should be ample to defend the works against boat attacks, which usually could not be effectively supported by the fire of the fleet at the moment of assault. Provision for quartering such a garrison will therefore suffice in planning the defences.

To determine the lines of the batteries which, in whole or in part, constitute the general tracé of the works, the following is the usual procedure. Circles are drawn on the map, with the battery under consideration as a centre. The bounding radii of fire will be determined by the width of field open to occupation by the fleet; and if this differs materially at the different practicable ranges, separate studies must be made and the best compromise be effected. Each mode of mounting has a maximum angle of distribution of fire—a revolving turret has 360 degrees, a casemate 60 degrees, an ordinary barbette 120 degrees, etc. If the desired bounding radii, fixed as already explained, include a less angle than that permitted by the selected mode of mounting, the crest of the battery will be a straight line perpendicular to the bisecting radius; if not, the crest should be a broken line—and in general an angle of about 60 degrees will be most advantageous. With casemates this angle is decidedly the best. Having drawn the crest-line upon the map, note whether or not it is exposed to be flanked or enfiladed by shipping, and examine the locality itself to learn whether a slight change of position would reduce the cost of construction. The different batteries are thus successively established.

The traverses and parados are next to be considered. Traverses are desirable between all large high-power guns mounted in barbette: (1) to supply

magazines and shell or loading rooms; (2) to prevent the blast of adjacent pieces from interfering with each other; (3) to limit the effect of an exploding shell; (4) to cover the guns against enfilade fire, if that be practicable from the water. On the other hand, if raised considerably above the level of the parapet, as has usually been the custom, they serve to define the exact position of the gun to the enemy; and, with the increased precision of fire to be expected from ships under favorable conditions, this is a serious objection. Some of the reasons for their existence do not absolutely compel them to be raised much above the crest of the parapet, and perhaps, where there is no danger of enfilade, future practice may limit them to that height. With disappearing guns, especially, this would reduce the target to a long, ill-defined line with nothing to indicate their position except an occasional appearance at the moment of firing.

Recent difficulties which have arisen in respect to the parados are more perplexing. Its only *raison d'être* is to afford protection against reverse fire, to which coast batteries are sometimes unavoidably exposed. No one has ever proposed to use the device unnecessarily, because when a projectile is coming over the parapet a highway to speed the parting guest is an instinctive provision. But experiment has shown that even when parados are unavoidable it it is not easy to fulfil the conflicting conditions they impose. Allowing for an angle of fall of 15 degrees, a parados must be placed quite near the gun or else be built to an excessive height. But if it be built too near, the effect of shells from the front, of the size now employed by ships, is disastrous. Quantities of earth, especially if frozen, stones, gravel, and splinters of shell, are thrown back so freely by such projectiles that the Italian engineers, after practical ex-

periments, have decided 95 feet behind the platform to be not an excessive distance for parados exposed to guns of a larger calibre than six inches. Up to and including that calibre 65 feet proved sufficient; field and siege guns caused no dangerous splinters. But a distance of 95 feet with a fall of 15 degrees calls for a parados rising at least 25 feet above the crest. Evidently they will be avoided whenever practicable, and, when unavoidable, will demand special studies in each case.

Of late the attention of engineers has been strongly drawn to the importance of concealing sea-coast batteries by every practicable expedient. To increase precision of fire, gunners on shipboard will take advantage of surrounding objects which have a known relation to the position of the guns, and they will correct errors in pointing by noting the bursting of percussion-shells, or columns of dust thrown up by shot. Hence those sites are most advantageous which do not favor such methods. For example, forests behind the battery give an uncertain horizon, while if the guns are clearly defined against the sky it is comparatively easy to adjust the sights. If the slope in front is wooded or grown up with brush it is not easy to perceive the exact point where a projectile has struck; while a battery placed upon a long, smooth slope which continues to rise to the rear, is as unfavorably situated as the bull's eye of a target. A battery retired a short distance behind the crest of a bluff affords a very uncertain clue to its range. A rocky slope increases the chance of ricochet shots taking effect, while a steep earthen slope stops the projectiles.

Evidently in the future we must sacrifice neat crests and beautiful slopes, so far as the service of the guns and protection against washing by storms will permit; trees and bushes must be planted on the

parapets and behind the batteries to prevent a clear definition of the guns; the latter themselves must be colored to harmonize with their surroundings in summer and winter; in a word, dispersion and concealment, as contrasted with concentration and armor, is the latest phase which the question has assumed. This solution has been strongly advocated by General Sir Andrew Clarke, recently Inspector-General of Fortifications in England; and no doubt, as ship-guns improve in power and accuracy, engineers will study every expedient to aggravate the difficulty of aiming from the unstable decks to which, fortunately for us, they are confined.

Another matter must not be overlooked in constructing batteries for high-power guns—the effect of the blast. The direct blow of the gases is not so severe as might be expected. A smooth layer of stone or concrete three feet thick, under and in front of the muzzle of a 12-inch gun, saves the parapet from degradation; but there is another effect which in confined positions is formidable. The partial vacuum created behind the blast has a tendency to burst open doors and light recesses, break windows, etc., by the pressure of the air behind them. This effect has long been noted at the explosion of magazines. Iron bars 2.5 inches wide and 0.5 inches thick, securing the doors of shell recesses, are reported to have been bent outward by the vacuum created by the blast of a 9-inch rifled gun. Large embrasures in casemates have caused the breaking open of doors of shot-lifts, and have shaken up the cannoniers most unpleasantly. To meet this difficulty, free passages for the air to enter should be supplied, and casemates should never be closed in rear.

Some experiments were made in 1872–73, in New York harbor, to test the effect of the blast of a 15-inch smooth-bore gun charged with 100 pounds of

mammoth powder and a shot weighing 460 pounds. The conclusion reached by the Board conducting the experiments was that a second battery 55 feet below the first and 200 feet in advance, the ground between being a somewhat broken slope of earth, would be beyond the range of injury from the blast or from unburned grains of powder; but at 54 feet in front and 12 feet below the muzzle there would be danger from the latter, a screen of inch boards having been riddled under like conditions. It was also inferred that intermediate irregularities of ground, in the nature of high screens, would tend to further reduce the effects of the blast at a second battery, and that a sufficiently high scarp (height not determined) would justify placing a second barbette battery at its foot. The Board, however, guarded itself by recommending that, before a second barbette battery was placed in front of the high battery, "a few experimental shots should be fired in order to test the force of the blast at points of the intended site."

I think that, with the high-power guns and slow-burning powder of to-day, no engineer would care to dispose two barbette batteries so that one should fire over the other, under conditions even approaching those favored by this Board.

In fine, then, a sea-coast fortress of to-day, suited to the needs of this country, consists of a central keep provided with bomb-proof quarters and arranged for a vigorous defence; of detached high-power gun batteries (turrets, iron casemates, lifts, barbette batteries for disappearing guns, open barbette batteries, etc., according to circumstances), so placed as to sweep the channel and approaches, but with ample space between their sites to prevent mutual interference; of detached mortar batteries, usually in rear of the guns, and, so far as possible, out of sight of the enemy; of machine guns in covered

positions to sweep slopes and approaches, and the interior of the batteries in case of surprise ; of wire and other entanglements to check the advance of the escalade parties from boats ; of secure operating rooms, cable-shafts, galleries, and flanking guns for the mined zones ; of position-finders suited to the locality, for determining ranges and controlling the fire of the guns and the operation of the mines from the station of the commanding officer ; of suitable arrangements for sweeping the approaches by the electric light, and for using movable torpedoes under control from the shore. In countries where there is danger of powerful descents upon the coast more attention is paid to the defence of the position against assault ; but with us little is to be feared in that direction. Few modern fleets could afford to land more than 1 500 or 2 000 men for that purpose, and, with our reserves of local troops added to the regular garrison, we should be able to hold the works with the preparations indicated.

The cost of such a fortress is less than might be imagined, and very far less than would be demanded by a system of floating batteries. Thus the Fortification Board, of which Secretary Endicott was president, after a careful study of the subject, estimated that the first cost of one floating battery, complete except the armament, would be $3 300 000. Let us see what could be prepared for that sum in the way of a sea-coast fortress, adopting a liberal scale of expenditure, increased in nearly every important item over the figures of that Board :

### FIRST COST OF A SEA-COAST FORTRESS COMPLETE, EXCEPT THE GUNS.

| | |
|---|---|
| One 2-gun turret for two 16¼-inch 110-ton guns | $1 000 000 |
| Ten lifts for ten 12-inch 50-ton guns | 1 000 000 |
| Ten disappearing batteries for ten 12-inch 50-ton guns | 450 000 |
| Three batteries for forty-eight 12-inch mortars | 192 000 |
| Four hundred mines and cables, etc., complete | 200 000 |
| Two operating casemates for the same, with cable shafts, etc | 100 000 |
| One keep, with flanking arrangements for the batteries | 200 000 |
| Add contingencies, 5 per cent | 158 000 |
| Total | $3 300 000 |

The floating battery carries two 16¼-inch 110-ton guns and one 10-inch 27-ton gun, and is exposed to torpedo attacks and to rapid deterioration. The fortress mounts two 16¼-inch 110-ton guns, twenty 12-inch 50-ton guns, forty-eight 12-inch mortars, four hundred mines with their adjuncts; and they are exposed neither to torpedo attacks, nor to escalade, nor to rapid deterioration. Bearing in mind the importance of economy, these figures permit of no difference of opinion as to how funds should be invested in cases where a land fortress will accomplish the desired object; and this is the case in all but two of our chief seaports.

### NAVAL CO-OPERATION.

We have seen that, from the standpoint of a military engineer, a sea-coast fortress bears a relation to

the naval strength of the nation similar to that of an entrenched camp to the land forces. It affords security to the port and depots, a refuge to the commercial marine, and a base of operations for the fleets. So far as the position permits, the means of defence should be confined to the land; in that way only can economy, permanency, and security against torpedo attacks be secured. Moreover, any floating defence is always liable to be transferred to some other field to meet a pressing emergency, real or imagined, and the enemy may thus succeed by skilful manœuvres in stripping his proposed point of attack of elements vital to its projected plan of defence. It is therefore an accepted axiom with us that, so far as possible, our system of land defences shall be independent of floating support.

But this, like all other rules, has its exceptions. Thus, for example, nature may offer no facilities for defensive works. A large city, like many of our Lake ports, lying upon a straight shore with no bay or river approach admitting of defence intervening between itself and an anchorage within bombarding range, is practically at the mercy of the power holding control of the water. Other sites, like San Francisco Bay, by reason of deep water, strong currents, and unfavorable topography, may justify the great cost of floating defences to complete the land system. Yet other sites, like the mouth of the Mississippi, may present engineering difficulties in the way of foundations which render it cheaper to float the heavy guns on water rather than on mud.

But in addition to these special cases where the aid of floating batteries is counted upon by the land forces, there is one duty of vital importance in a vigorous defence which is solely naval. No entrenched camp would be left without outposts to watch the approach of the enemy, or without sorties to harass

him when he has made his appearance. The land defences are immovable and would lose half their value if not supported by an active naval force. It is not great guns that we shall need; they can usually be mounted far more economically on land. It is the power of making offensive returns, in the nature of sorties, that we lack; and for supplementing this deficiency we shall everywhere need naval co-operation. Present indications lead to the belief that the modern torpedo-boat is fitted for this work. Its high speed would render it as useful as is cavalry for scouting; its terrible weapon would make it more dreaded than the "masked battery" so often heard of in the early days of the civil war; while its power of combining in flotillas, and assailing individual armored ships of the first-class by night or when obscured by the smoke of their own guns, might lead to results as decisive as those achieved by the column of Macdonald on the field of Wagram.

These needs in our latest system of coast defences are strongly appreciated by engineers, and we hope that they may be seriously considered by naval officers, who will know how they can best be met by existing or by modified types of torpedo-boats. I cannot but believe that in no other form can funds for "coast defenders" be so usefully applied. Our forts have been likened to chained watch-dogs, and in one sense it is a true comparison; but we must not forget that the dog is chained in front of the office safe, where he is most needed, and that there are better ways of assisting him than by locking an unchained friend in the same apartment.

# INDEX.